# 1997-98 CIMMYT Annual Report

# Change for the Better

Contents

# A Message from the Director General

As stated in last year's *Annual Report*, we are in a process of transformation at CIMMYT in order to reposition the Center to meet the changing needs of our many partners and the new global challenges which together we must overcome. We believe that significant progress has been made in the past three years, ensuring the strengthening of CIMMYT as a modern, first-class international research institute. Perhaps the single most important evaluation of progress in 1997 was the External Program and Management Review, which concluded that:

> The Centre conducts high-quality science and has an impressive record of achievements as well as impact on the daily livelihood of hundreds of millions of rural and urban poor. CIMMYT is well managed, has strong leadership, and is a flagship centre of the CGIAR System. The Panel firmly believes that CIMMYT merits continued strong support from the donor community. CIMMYT is providing much-needed services and products for which it has a definite comparative advantage and for which there are no alternative suppliers. There is no perceived diminution in the uptake of CIMMYT's enhanced germplasm by NARSs throughout the world. There are also substantial spillovers to other organizations in countries that are financial partners of the CGIAR . . . . The Centre is not resting on its laurels, but is taking steps to position itself strategically to meet the challenges of a changing internal and external environment.

In this year's *Annual Report*, we take the opportunity to review several facets of our changing environment, especially in the regions where we work, and to review our role as an agent of change. With our partners, we share the belief that research towards sustainable agriculture in developing countries is one of the few ways to bring about positive change in an increasingly volatile era. We know from experience that research has impacts that extend beyond farmers' fields to many areas of global concern. These concerns include the civil and economic stability of nations; the availability of food and better nutrition for poor people, wherever they live; and the preservation of genetic and other natural resources that are the foundation of a stable, more productive agriculture. Unfortunately global support for agriculture continues to decline, and I believe that we have grossly underestimated the challenge of meeting the 2020 targets for food production. There is a belief in many quarters that food comes from supermarkets, but in reality it comes from farms—farms that are subject to constantly changing pests and diseases; to heat and to drought; to cold and to waterlogging. If these farms and farmers are indeed to meet the challenge of doubling food production in the next 20 years, they require a constant supply of new technologies and skills—the products of research and development. We and our partners still believe that our research can make a difference in the lives of poor farmers and consumers.

How does CIMMYT bring about change for the better? We have significantly re-positioned the Center to meet the demands of our partners, both South and North. A more inclusive and participatory process in the workplace—encompassing issues of gender and diversity—has been reflected by changes in research management. We have established multidisciplinary project teams whereby plant breeders, biotechnologists, physiologists, agronomists, economists and other social scientists, and natural resource specialists work together to achieve the outcomes described in our *Medium-Term Plan (1999–2001+)*. As I have indicated in a recent publication, *Sustainable Intensification of Agriculture*, we have also adopted a new research paradigm—germplasm x environment x management x people—that fosters a broader range of external partnerships with national research systems, non-governmental organizations, advanced research institutes, other international research centers, and, where appropriate, the private sector.

**"Unfortunately global support for agriculture continues to decline, and I believe that we have grossly underestimated the challenge of meeting the 2020 targets for food production."**

## Highlights of This Report

Paradigms are powerless to foster change unless they are grounded in reality. As virtually every story in this report demonstrates, the impacts of our research originate in an unequivocal understanding of real dilemmas facing real farmers in developing countries.

**From the ground up.** By remaining in touch with events in the field (a precept taken to heart by every CIMMYT scientist from Borlaug and Wellhausen to their successors), we seek to conduct the right kinds of research, with the full range of partners who wish to be involved. Our report begins with a close look at recent research to alleviate failing soil fertility in sub-Saharan Africa; new methods for curbing the harmful effects of excessive nitrogen use in Latin America; and tillage systems to foster food security in South Asia. What these and the other stories in this section show is that all of us—researchers, farmers, and other partners—are deeply engaged in learning how our combined skills can improve conditions at the farm level.

**Secrets in the seed.** The second section of our report highlights efforts to ensure that new knowledge and information are transformed into technologies that farmers can use. For example, we have started to investigate the economic efficiency of alternative strategies for locating useful material in gene banks. An even more exciting development concerns new approaches to biotechnology networking and capacity building, which may significantly alter the pace of change in biotechnology research in developing countries.

**The test of time.** The farmer's field, where the diverse challenges to sustainable agriculture are manifested, is the crucible where technologies are tested over time. The third section of our report begins with a story of how a technically sound but previously untried strategy to breed for disease resistance has paid enormous dividends since it was adopted nearly 30 years ago. We also examine the impact of a long-term maize research project in Ghana. To some extent, a technology's ability to meet the test of time depends on how well researchers have identified farmers' needs. The last story in this section gives some idea of the role that projections can play in setting the future course of research in a very unsettled world; it describes how the current crisis in Asia may affect the supply and demand for wheat and maize.

**A view of future impacts.** Our final stories show what the world can expect from us in the future—including farmer participatory research methods, new methods for assessing the effects of genetic diversity on crop productivity, and an ambitious study of research efficiency in Latin America.

## Research for a Changing World

This *Annual Report* describes the many ways that innovation is alive and well at CIMMYT. In 1997–98, we continued to dedicate considerable effort to understanding and remaining flexible in a research environment where developments in technology, intellectual property rights, private- and public-sector interactions, and new funding arrangements profoundly influence the way we work.

One notable change during the year was that Shivaji Pandey, a respected researcher and leader of a highly successful regional maize research effort for CIMMYT, was named Director of the Maize Program. Among the major strategic directions Pandey outlines for the Program is a steady focus on solving the problems of resource-poor farmers. The Maize Program must strike a proper balance between technologies for subsistence farmers and products for commercial farmers. This will mean even greater efforts to develop and disseminate stress-tolerant, input-efficient, low-cost maize varieties and cropping systems that reduce the risk for small-scale farmers, providing reliable yields across years and under forbidding conditions.

New offices were opened in China and Kazakstan, where we are optimistic that stronger involvement in the field will strengthen collaborative research accomplishments. A special series of events celebrated the longstanding collaboration between India and CIMMYT and laid the groundwork for the future. One of our researchers, Marianne Bänziger, received the CGIAR's Promising Young Scientist Award in recognition of her work on stress-tolerant maize. Finally, we have encouraged greater research communication by sponsoring and participating in numerous conferences, including an international symposium on the genetics and exploitation of heterosis in crops, and regional wheat and maize workshops.

This short introduction to our report can convey only an impression of the tremendous energy and dedication that our researchers and partners bring to the challenges of agriculture in a changing world. The stories that follow give a more detailed picture of the opportunities and exigencies of our work. Change is inevitable, and we at CIMMYT have the responsibility to ensure that our legacy to the world is a series of innovations that enable change to occur in a positive way.

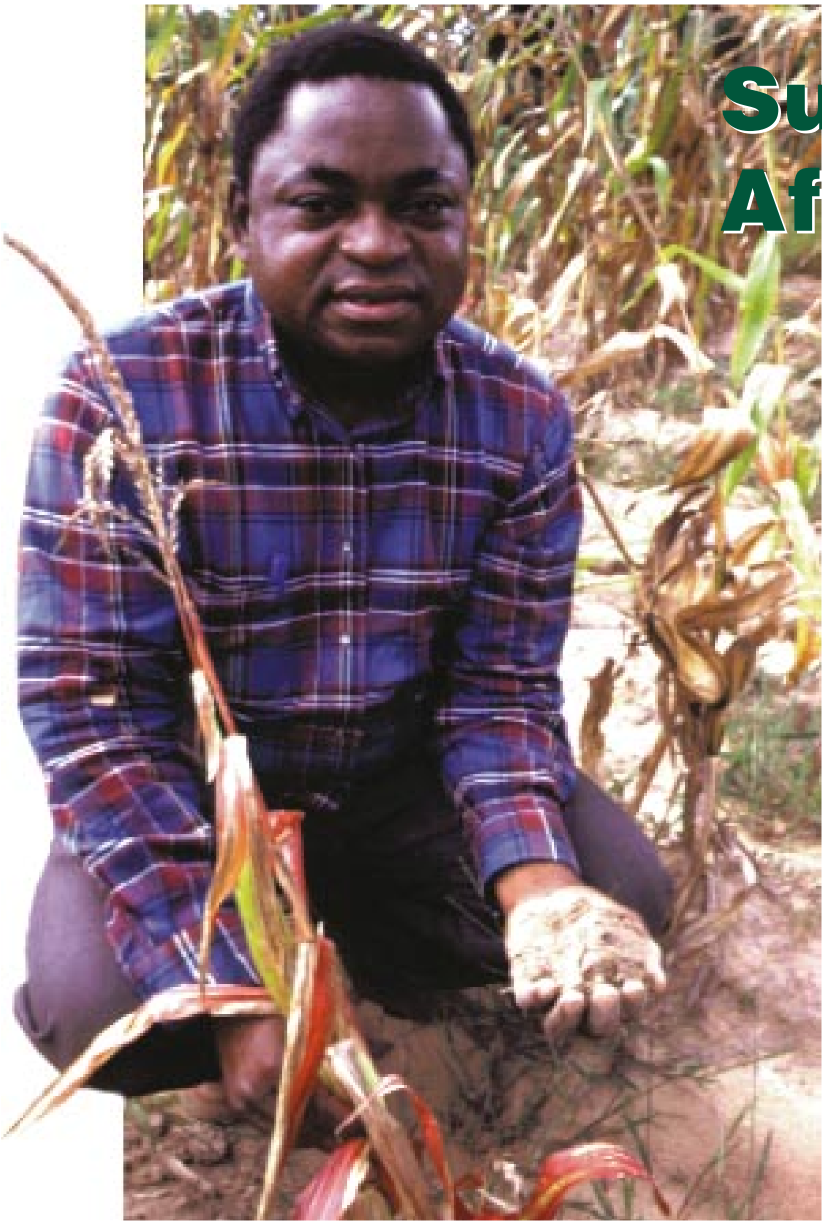
Timothy Reeves

Prof. Timothy G. Reeves,
**Director General**

# From the Ground Up:

# Coping with Changing Environments

Change for the Better



# Sub-Saharan Africa:

## Over-taxed Soils Imperil Food Security

Land is our traditional measure of wealth, ultimate resource, and the foundation of the slender biosphere we inhabit. The ancient Greek term for farmer, *geórgos*, literally means "one who works the earth." Mother Earth has richly rewarded the efforts of those who till her, but now the **harmony of humankind's ancestral pact with the land is breaking down**. The consequences may be most severe for the people of Africa.

In few places is the issue of soil productivity more important than in the sub-Saharan African nations of Zimbabwe and Malawi. In both countries maize is the chief staple. Hybrid seed is widely grown, but generally on infertile land with little fertilizer or other inputs. Rising populations have brought on intensified cropping; land-restoring fallows—once a common practice—are only a memory. Farmers increasingly lack cash, have few opportunities for off-farm employment, and live with the constant menace of hunger because their nutrient-poor fields cannot yield enough.

"Nine-tenths of smallholder farmers in Zimbabwe grow their crops on sandy, granite-derived soils that are very old and depleted of nutrients," says Stephen Waddington, maize agronomist at CIMMYT's office in Harare, Zimbabwe. "Fertility is so low at some sites that growing a crop is almost like hydroponics. Few farmers can afford chemical fertilizer."

In densely populated Malawi, once-fertile soils have been mined by decades of intense, subsistence cropping and residue removal. Recent currency devaluations and the elimination of subsidies have pushed fertilizer beyond farmers' reach. As a consequence, productivity and household food security have sunk to dangerous levels.

## The Network that Helps Smallholders

In 1994 Waddington brought together a network of soil fertility scientists from Malawi and Zimbabwe to help address these concerns for maize-based farming systems. With funding and guidance from the Rockefeller Foundation, the soil fertility network (SoilFertNet) has provided a crucial venue for setting priorities, allocating resources, sharing information, and, through Waddington and CIMMYT, obtaining first-rate technical input and training. “Southern Africa had a long history of research on soil fertility, but little research had been clearly directed to the needs of small-scale farmers,” Waddington says. “We wanted researchers to become aware of what colleagues elsewhere were doing and of which technologies could make a difference, enabling everyone to focus scant resources on key areas. Most importantly, we wanted to improve communication among researchers, extension workers, and farmers.”

In four short years, SoilFertNet has effectively cross-linked contributions from an impressive range of sectors—advanced research institutions, international research centers, other public research and extension agencies, donors, national policymakers, non-governmental organizations, and (last but not least) farmers. In network-supported projects, soil and crop scientists collaborate with economists, anthropologists, and geographic information systems specialists, to name a few disciplines. Joint planning and priority setting have kept activities closely attuned to the problems and opportunities of smallholders in Malawi and Zimbabwe. The production and distribution of a range of publications have improved the capacity of participants and increased general awareness of soil fertility issues. Finally, the network has helped members improve the quality and appropriateness of their research proposals. This, together with the strength and importance of research conducted through SoilFertNet, has empowered its members to seek additional financial support, one key to ensuring that this badly needed work continues.

A notable achievement of the network is its “best-bet” technologies—especially more efficient organic and inorganic fertilizer practices and the use of various grain legumes or green manures in association with maize. These technologies are designed to boost harvests quickly and profitably on the poor soils typical of small-scale maize production.

## Naturally Nodulating Soybean to Supplement Maize

An example of a “best bet” technology is the soybean variety Magoye, studied and promoted by University of Zimbabwe researcher Sheunesu Mpepereki. Unlike typical commercial varieties, Magoye requires no bacterial inoculation to fix nitrogen in the soil and yield well, making this naturally nodulating variety a natural for smallholder farms. “Growing soybean is one of the most viable ways to improve the sustainability of maize-based smallholder systems in wetter parts of Zimbabwe,” Mpepereki says. “In soybean, you have a food crop, a cash crop, and a soil-improving crop—very few plants give you that combination.”

“Soybean is a crop many farmers want to adopt,” says Jesmael Mushai, who farms less than three hectares of mixed maize, soybean, groundnuts, pepper, sweet potatoes, and bambara nut in the Mhondoro Communal Lands, Chegutu District, southwest of

**Researcher Sheunesu Mpepereki hopes the rotation of naturally nodulating soybean with maize will boost productivity on unforgiving farmlands in Zimbabwe. His interest in helping farmers stems partly from his upbringing in the Midlands Province, one of the nations’s poorest agricultural areas. “I don’t know how my parents made it. If you look at everything that could possibly be wrong for agriculture—sandy, shallow soils, bad rainfall distribution—you encounter it there.”**

Harare. Why? “Because it requires fewer inputs than other crops, it is nutritious, and when you market it, the price is better than for maize," Mushai says. A coalition of farmer unions recently endorsed naturally nodulating soybean in a position paper for the government of Zimbabwe. Given the advantages of soybean–maize systems and farmers' interest, SoilFertNet members recently agreed that this technology warranted "fast-track" promotion in Zimbabwe.

## Malawi: Food Security in Crisis

Network-derived benefits are not limited to the field, but also reach farmers via informed policy decisions that support economic growth while staving off food shortages, as occurred recently in Malawi.

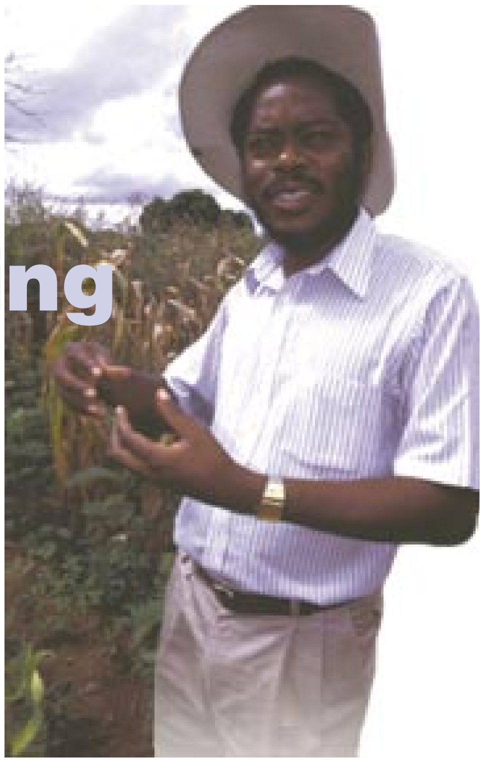
In February, 1998, observers spoke of a rising sense of panic throughout this landlocked, southern African country—grain stores from the previous season were exhausted, the harvest was not ready, and nobody could get maize. Maize prices at local markets had skyrocketed. People were buying the bran (normally used to feed animals) off the floor at maize mills, and there were reports of widespread theft of green ears in ripening fields and even experimental plots. When the harvest began in mid-March, tensions eased and maize prices quickly dropped to near-normal levels, but the early draw-down on grain is likely to hasten the onset of the hungry season in late 1998 and early 1999. Indeed, many experts fear that this year's shortfall was not an exception, but a foretaste of chronic shortages to come.

"I don't think people appreciate how difficult a situation Malawi is in right now," says Malcolm Blackie, senior scientist in the Rockefeller Foundation's Agricultural Sciences Program. “Most Malawians suffer an average two-to-three month deficit in maize production and must pay as much as four times the official purchase price for maize. To understand what this means, recall that 80% of rural Malawians have an average annual *cash* income of less than 15 US dollars.” Poor harvests are a basic cause of Malawi's pervasive malnutrition and of a child mortality rate that ranks among the world's highest.

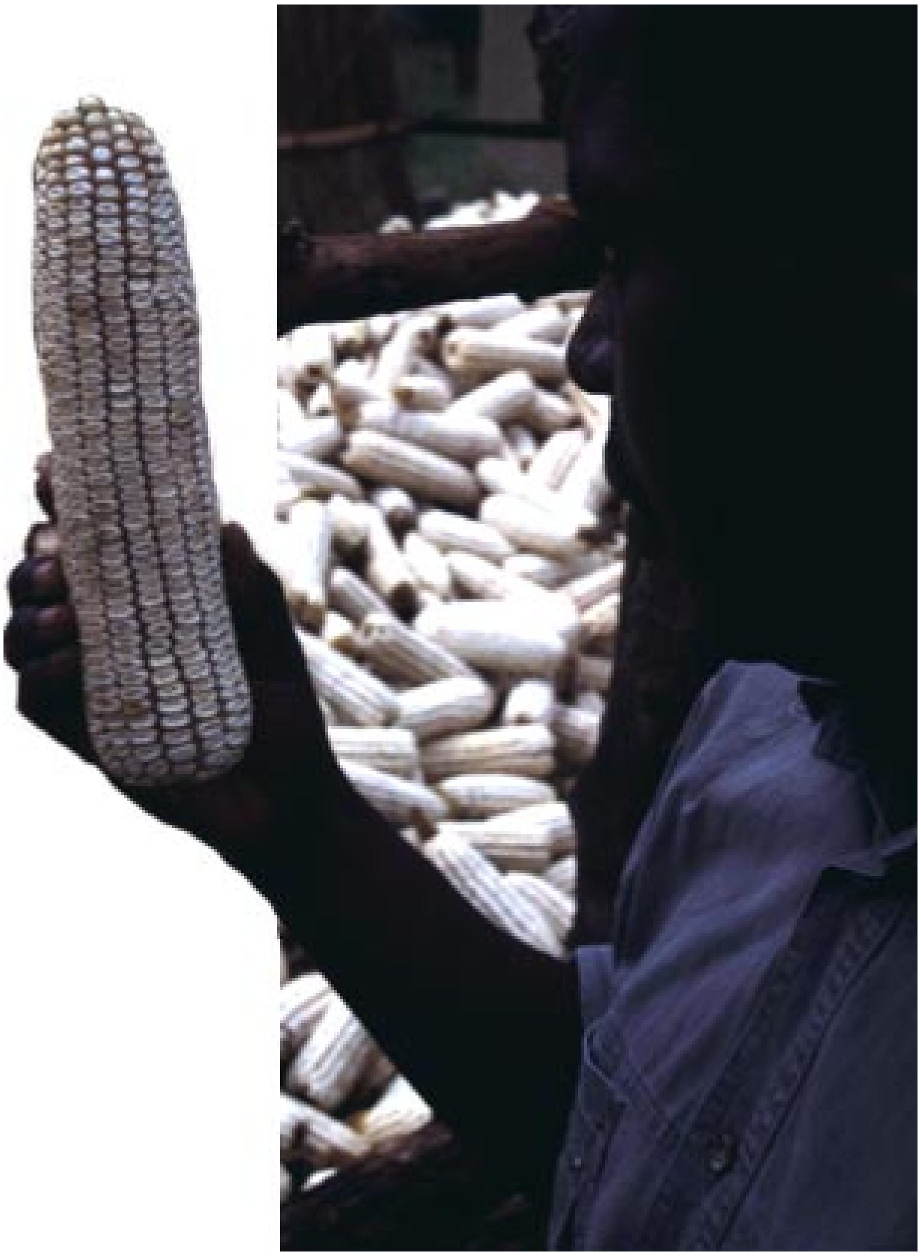
Seeking help on the best way forward for this chiefly agricultural nation, the government sought advice from many quarters, including the Rockefeller Foundation, which in turn called upon SoilFertNet. "Scientific results must get into policy," Blackie explains, "so we used network studies to put together a report on what was feasible and what was not." The major conclusions? Population growth in Malawi would continue to exceed food production increases into the foreseeable future. "But ways of achieving long-term food security other than subsidies must be sought," Blackie says. The report's suggestions thus include providing *all* smallholders with small packs of improved maize seed and fertilizer as a near-term measure to avoid serious food shortages. A coalition of donors has agreed to support this move for the 1998–99 cropping season.

## Multicropping: The Organic Option

Together with its short-term recommendations for averting disaster, the report also urged intensified efforts to foster use of *organic* fertilizers—particularly grain legumes—which can improve household nutrition, furnish cash, and reduce the need for chemical fertilizers, while constituting something that farmers really want to grow. Research along these lines has been one of the main endeavors of Alex B.C. Mkandawire and George Kanyama-Phiri, agronomists at Bunda College of Agriculture, Malawi, who work with farmers and extensionists near Zomba in the south. Population density there can be as high as 500 persons per square kilometer, according to Mkandawire's estimates, and most farmers have but an acre of land (0.4 hectare) or less to support their entire family. Mkandawire's on-farm experiments test varied crops and approaches, including undersowing green manures such as *Tephrosia* and *Crotalaria* into the maize, or rotating maize with a soybean–pigeonpea intercrop. "We want to see how far we can go in reducing inorganic fertilizer by using organic technologies," Mkandawire says. Another promising organic option is to sow pigeonpea directly into the maize crop. The pigeonpea grows slowly early on, and it can be harvested later than the maize, Mkandawire explains. "In addition, there's a considerable local market for pigeonpea; it's used by a community of Asian immigrants to make *dal*.”



## Is Disaster Inevitable?



Though pleased with progress to date, Waddington admits to the need for more concerted action on soil fertility management. "Developing and disseminating relevant soil management practices for smallholders ultimately depends on many people in many countries interacting in new, more productive ways," he says. Smallholder maize farmers in southern Africa, for example, are quite diverse in their circumstances, practices, and problems, implying the need for a systematic classification into strata of coherent, useful size and, perhaps, a greater focus on farmers with the fewest resources. "We also need to involve farmers even more in problem-solving, ensuring that potential solutions are not just affordable but profitable."

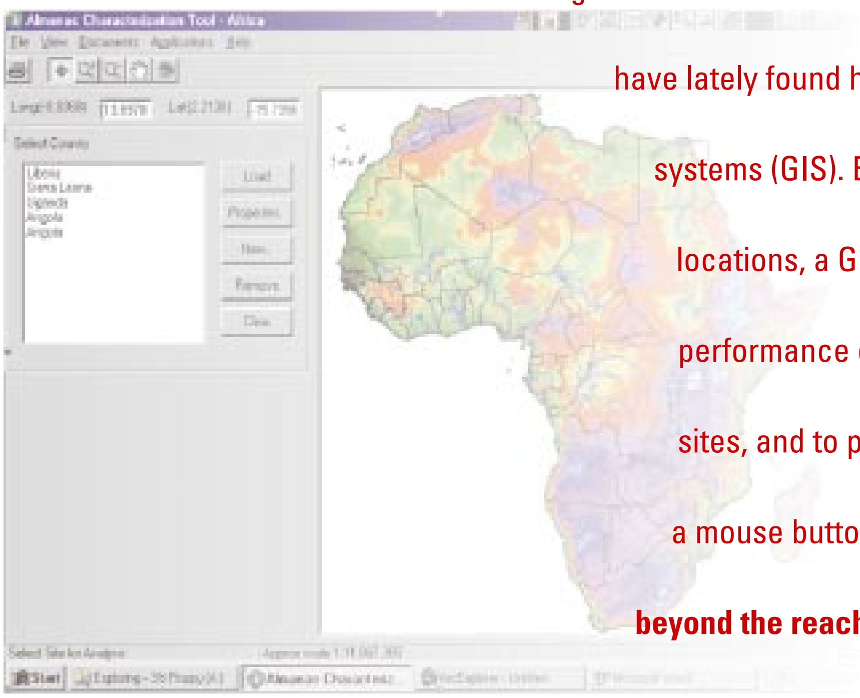
A greater concern in the region, perhaps, is the long-term sustainability of smallholder maize systems themselves. Most experts concur that nutrient removal through agriculture continuously exceeds nutrient inputs, and a net loss of organic matter is degrading the soil structure and quality. "Fertilizer is currently priced beyond the means of most farmers," Waddington says, "and strategies that depend on organic nutrient sources alone simply cannot provide the yields required for the region's growing populace."

Still, if there is one impression that researchers regionwide share, it is that smallholder farmers are extraordinarily *good* at what they do. "With the scant land and money they possess, it's simply amazing that they somehow manage to make ends meet," Mpepereki says. Given a few more resources and profitable production options, farmers and their age-old partner, Mother Earth, may pull off a miracle to surprise even the experts. One option that will help farmers get the most from the little fertilizer available, according to Waddington, will be new, low nitrogen- and drought-tolerant maize varieties being developed by a network of breeders in southern Africa, under a project funded by the Swiss Agency for Development and Cooperation and executed through the CIMMYT-Zimbabwe office.

More Information: **s.waddington@cgiar.org**

# Africa Country Almanacs:

## GIS for National Programs Now!



Agricultural scientists who seek their bearings on the high seas of data have lately found help in the form of geographic information systems (GIS). By linking environmental data to specific locations, a GIS allows users to examine, say, how performance of varieties or agronomic practices varies across sites, and to perform a range of other functions, at the click of a mouse button. The fingertip functionality of **GIS has remained beyond the reach of many CIMMYT research partners in the poorest areas of the developing world for a simple reason—it has required specialized applications that run only on high-powered computer work stations. That is, until recently.**

Now, with funding from the US Agency for International Development, the Integrated Information Management Laboratory (IIML) of Texas A&M University, together with CIMMYT's Natural Resources Group (NRG), has developed stand-alone, CD-ROM software that incorporates powerful and flexible GIS tools for agricultural and natural resource workers in Africa.

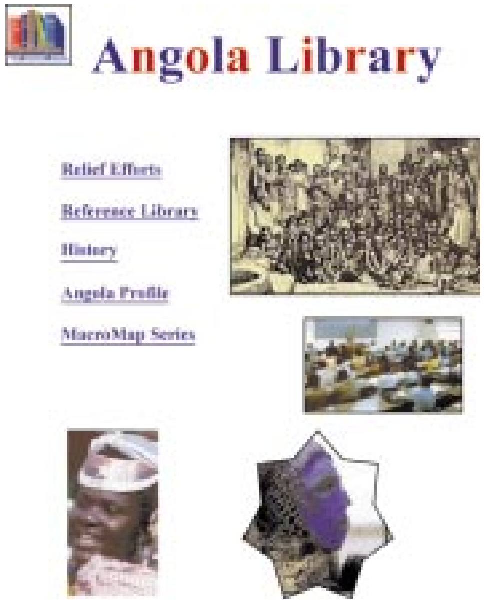
"The *Africa Country Almanac*, as this product is called, puts the enormous power of GIS in the hands of researchers who serve the world's neediest farmers," says Jeff White, head of CIMMYT's GIS Laboratory and NRG scientist.

### Accessible Tools and Information

Developed for users ranging from scientists to policymakers, the Almanac offers a suite of accessible tools and country-level data, as well as textual information, enabling researchers to explore questions such as:

- How representative of the country as a whole is a specific study site?
- What is known about the performance of new management practices or varieties in defined production environments?
- To which regions or sites will a newly developed management practice or crop variety be best suited?
- Which regions or sites fit a specified altitude and precipitation range and land-use category?

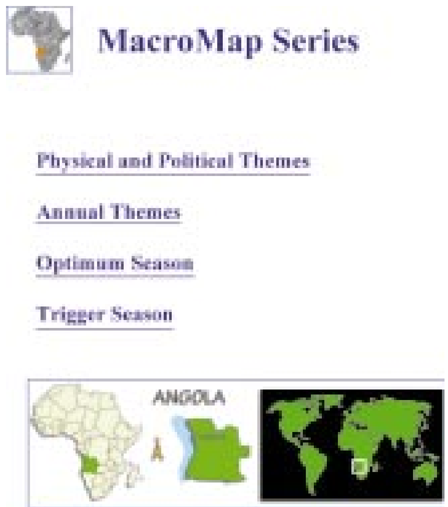
Users can manipulate and combine datasets and search results to create customized maps and tables. These are easily exported to word processing, spreadsheet, graphics, or other packages. Text information in the Almanac includes Internet sites, major articles and journals relating to the country, general background information, popular field manuals and other selected CIMMYT publications, and a collection of ready-made maps.




## Almanacs Already Available

Almanacs are currently available for researchers in Angola, Liberia, Sierra Leone, and Uganda and are in development for Eritrea, Ethiopia, Kenya, Malawi, Somalia, Tanzania, Zambia, and Zimbabwe. They will be distributed free of charge in sub-Saharan Africa.

"This product demonstrates what we feel is the proper role for GIS at CIMMYT," White says. "Our presence here is comparatively small, but we are building strategic alliances with other groups, like the IIML, who have access to resources and evolving technology. In this way, we can offer the best of that technology to partners in developing countries."




Piloting of a test version with researchers and national program partners at CIMMYT headquarters in early 1998 led to several improvements, including development of on-line tutorials that walk new users through Almanac functions using real-life scenarios.

## Plans for Further Development and Training

Besides increasing the number of countries covered, Almanac developers are working to upgrade its search and analysis capabilities and to include key crop and farming systems databases, such as the International Crop Information System (ICIS) and the Sustainable Farming Systems Database (SFSD).


The CIMMYT–Texas A&M team demonstrated the Almanac at the Regional Maize Conference in Addis Ababa, Ethiopia, in September, 1998—the beginning of CIMMYT's promotional and training efforts for the product in the region. "This is an entry-level package that nonetheless offers genuine GIS capabilities and will raise researchers' awareness and expectations concerning this technology," White says. "What is nice is that our national program partners can have something to use right now, rather than waiting to set up a sophisticated GIS unit ten years down the line."

More Information: **j.white@cgiar.org**

# Feeding the World or Fouling the Planet?

How do we feed future generations without harming the environment? This question has been asked more often than answered. Now **researchers at CIMMYT and Stanford University** are devising practical crop management strategies that reduce nitrogen trace gas emissions and remain economically attractive to farmers.

## The Question

Higher yielding wheats are absolutely essential to generate the huge quantities of grain (an estimated 1 billion tons annually by 2020) needed to feed a world population that is growing by nearly 100 million people every year. At the same time, the amount of farm land per capita is decreasing the world over due to soil erosion, encroaching human settlement, and industrialization.

"If we want to harvest more grain from the same or maybe even less land than we have today, we need nitrogen," says wheat agronomist Ivan Ortiz-Monasterio, who leads CIMMYT efforts aimed at improving wheat's nitrogen use efficiency. The ultimate goal is to limit the environmental consequences of using nitrogen fertilizer.

Nitrogen fertilizer applications are expected to increase greatly over the coming decades, with two-thirds of the increment taking place in the developing world. Increased use of nitrogen fertilizer will come at a cost. It will engender higher losses of contaminating nitrate from soils to freshwater and marine systems and of nitrogen-containing gases into the atmosphere. Fertilized agriculture is the biggest source of human-generated greenhouse gases such as nitrous oxide, and it also produces high emissions of nitric oxide, a precursor to acid rain. These processes, left unchecked, could cause serious ecological damage, both at the regional and global levels.

Researchers have been handed a terrible dilemma. How can the world continue to produce sufficient food without harming the atmosphere and regional water supplies?

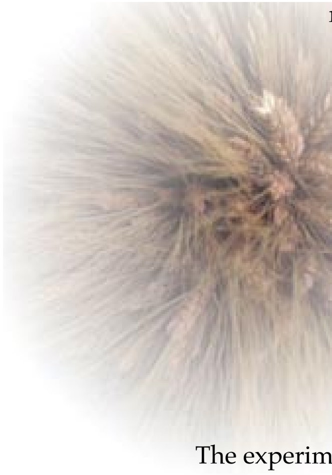
## The Answer

Solving this dilemma requires a type of research that many do not associate with CIMMYT's "traditional" work. But, in fact, CIMMYT research *has* contributed significantly to reducing nitrogen losses into the environment. Current CIMMYT-derived wheats produce more grain per unit of applied fertilizer than the older varieties they have replaced (*see figure*). To go with these wheats, CIMMYT has evolved agronomic practices that promote better nitrogen uptake by the wheat plant and more targeted, less wasteful use of nitrogen fertilizer by farmers. More recently, CIMMYT, in collaboration with institutions of higher learning such as Stanford University, started investigating what happens to nitrogen once it is applied—how much is wasted, how much is emitted into the atmosphere or escapes into the soil, and how much is actually assimilated by the crop. This research is providing a better understanding of how nitrogen fertilizer could be utilized more judiciously. Researchers are also looking at the economic costs of nitrogen losses and of strategies for reducing them.

"Sustainable agriculture requires striking a balance between reaching productivity goals and reducing the impact of farming on soil, water, and air," says Pamela Matson of Stanford University's Institute for International Studies. "But technologies that lessen the impact of nitrogen on the ecosystem have to maintain yields and make economic sense to farmers. Otherwise they won't be adopted."

## New Study Breaks New Ground

Previous research had not focused on developing agronomically feasible management practices that could reduce nitrogen trace gas emissions and remain economically attractive to farmers. To bridge this gap, Ortiz-Monasterio, in conjunction with researchers Matson and Rosamond Naylor, also of Stanford University's Institute for International Studies, undertook a study aimed specifically at evaluating the environmental, agronomic, and economic aspects of how fertilizer is managed in the Yaqui Valley, Sonora, Mexico. The Yaqui Valley is representative of the highly productive irrigated systems that produce 40% of the wheat in the developing world. The area provides a gauge of what is likely to occur in similar parts of the developing world that are critical for wheat production.

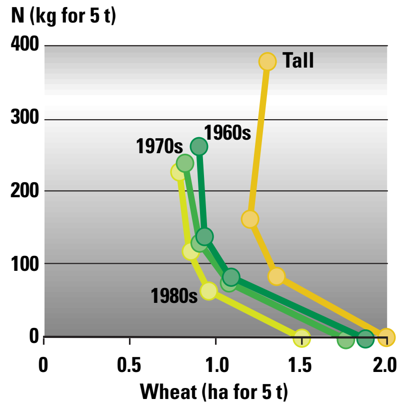


Started in 1994, the study evaluated changes in soil nutrients and gas emissions before and after fertilizer applications and compared alternative ways of applying nitrogen, including the farmers' common practice. The results appeared in the journal, *Science*.*

The experiment compared Yaqui Valley farmers' common practice with several alternatives that included reducing the amount of nitrogen applied and changing the timing of its application. The researchers found that with the farmers' practice (250 kg/ha of nitrogen, two-thirds applied a month before planting and before irrigating), relatively high levels of nitrogen are lost into the atmosphere when nitrogen comes into contact with irrigation water, even before the crop is in the ground. The best practice reduced the amount of nitrogen to 180 kg/ha (one-third applied at planting and two-thirds six weeks after planting) and produced similar yields and grain quality as the farmers' practice.

The best alternative practice also saved US$ 55–76/ha (equivalent to saving 12–17% in after-tax profits) by reducing fertilizer applications and nitrogen loss. Since fertilization is the highest production cost in the Yaqui Valley, these potential savings may induce farmers to alter their nitrogen management strategies. Indeed, on-going surveys indicate that some farmers are now postponing their first fertilizer application until planting.

This study shows that it *is* possible to reduce nitrogen gas emissions and fertilizer losses through appropriate agronomic practices and, at the same time, to maintain yields. With a greater knowledge about the efficient use of nitrogen, farmers could apply these practices instead of higher nitrogen doses. The ultimate effect would be to reduce the environmental costs of agriculture, both in the Yaqui Valley and the rest of the planet.



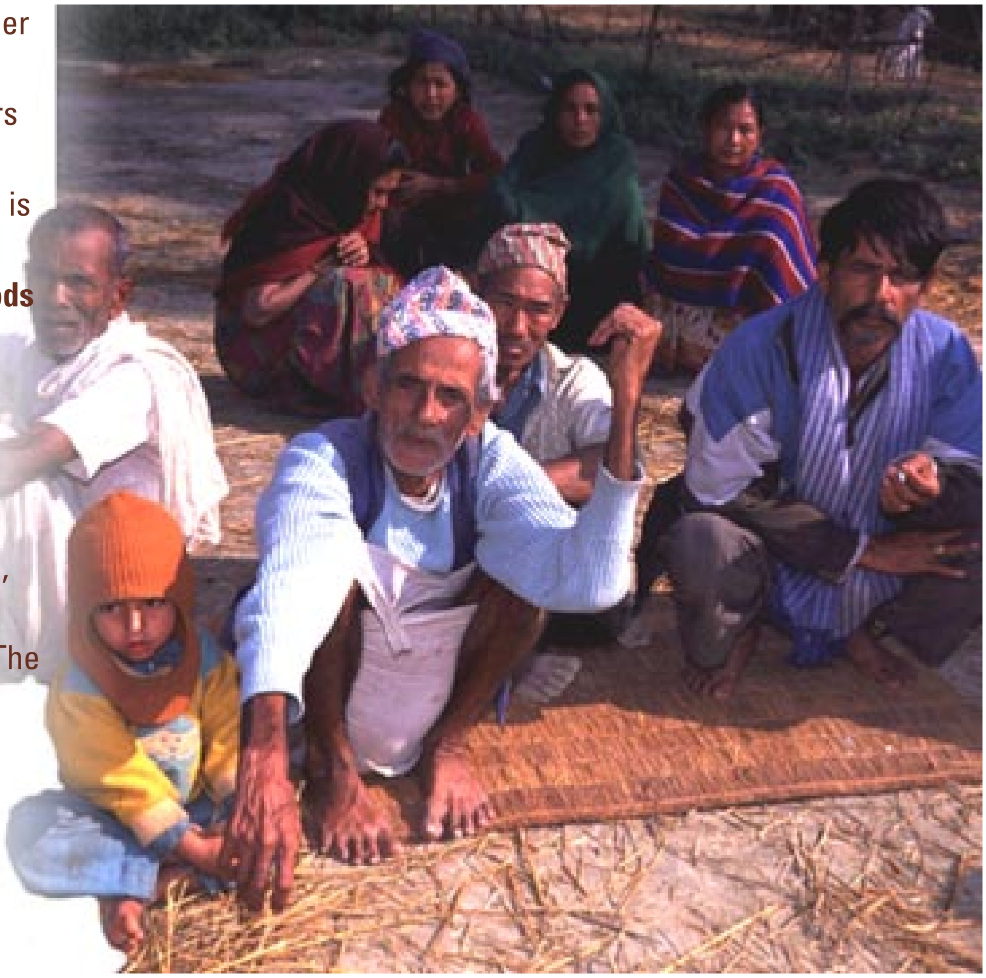

**Kilograms of nitrogen required to grow 5 tons of wheat. From right: *Tall*, two tall cultivars of 1950 and 1960; *1960s*, three semidwarfs of 1962-66; *1970s*, three semidwarfs of 1971-79; and *1980s*, two semidwarfs of 1981 and 1985.**
Source: Calculated by Waggoner (1994) from data in Ortiz-Monasterio et al. (1996).

More Information: **i.monasterio@cgiar.org**

* **Matson, P.A., R. Naylor, and I. Ortiz-Monasterio. 1998. Integration of environmental, agronomic, and economic aspects of fertilizer management. *Science* 280:112-114.**

# New Tillage Systems Help Rice–Wheat Farmers in South Asia Meet Food Needs

Through the Rice–Wheat Consortium, CIMMYT, together with farmers and researchers from Nepal and Bangladesh, is examining **two tillage methods that promise to make agriculture in South Asia a more sustainable enterprise**, even for very poor farmers. The first is an inexpensive hand tractor and implements; the second is surface seeding of wheat.



Farmer Participatory

## Farmer Participatory Testing of the Chinese Hand Tractor

"The hand tractor is a small-scale technology that's raised agricultural production throughout Southeast and East Asia," says Scott Justice, a graduate student in anthropology from the University of Kentucky who is working with CIMMYT in Nepal. Through the Rice–Wheat Consortium, CIMMYT has imported Chinese hand tractors and attachments into South Asia, trained farmers in their use and maintenance, and (more recently) helped farmers and local researchers test the technology at selected rice–wheat sites in Nepal and Bangladesh. More than 200 farm households test-drove the tractors and accessories under this program during 1996–98. Farmer participation has been a crucial element of the work from the outset, as well as interdisciplinary cooperation among researchers, extensionists, and non-governmental organizations. "We were there to help farmers plan and implement the research, but trials in both countries, along with the tractors themselves, were farmer-driven and managed," says Craig Meisner, CIMMYT Natural Resources Group agronomist in Bangladesh.

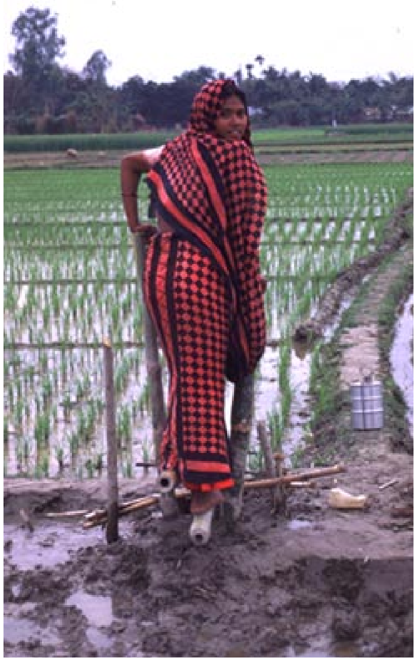
## The Results

Results at one Nepali test site this past year were dramatic, according to Justice. "Because it rained in early December, fields were too wet to prepare the land for timely sowing of wheat after rice harvest—even experiment station staff had trouble. In contrast, fields established using the Chinese hand tractor or surface seeding were sown as much as six weeks earlier, had very good stands and plant development, and wheat appeared much less susceptible to heat stress later in the season." According to Larry Harrington, Director of CIMMYT's Natural Resources Group, which leads the Center's participation in the Consortium, the new practices raised productivity dramatically. "Farmers have been astonished at the excellent performance of the options, especially during the current crop season," he says. "At some test sites the new practices made the difference between a yield of three tons per hectare versus no crop at all." Harrington also cited the enthusiasm of farmers in several villages about being able to fit in a third crop (maize, beans, vegetables) after the early planted wheat as a result of the new practices.

## A Range of Options and Opportunities

The key advantage to using the tractor is its implements, which include a special seed drill, a reaper, a pump, and a trailer, among others. For instance, what the seed drill can accomplish in a single pass—

**Research Partnerships for Rice–Wheat Systems:** South Asia's rice–wheat cropping systems cover 12 million hectares and are the foundation of food security, employment, and income generation for well over 350 million rural inhabitants. Faced with increasing evidence of slowed or stagnating growth in system productivity, despite use of improved varieties and recommended inputs, researchers and farmers are seeking new ways for sustainably raising rice–wheat harvests.



**Rice–Wheat Solutions:** The Rice–Wheat Consortium for the Indo-Gangetic Plains is an ecoregional program of the Consultative Group on International Agricultural Research (CGIAR), aimed at enhancing the productivity and sustainability of rice–wheat cropping systems in South Asia. Partners include the national agricultural research systems of Bangladesh, India, Nepal, and Pakistan; international agricultural research centers (CIMMYT, the International Crops Research Institute for the Semi–Arid Tropics, the International Rice Research Institute, and the International Water Management Institute); and Cornell University. As of November 1998, CIMMYT will become the convening CGIAR center for this ecoregional program. Research in Nepal was initially funded by the US Agency for International Development, with additional support from the Australian Centre for International Agricultural Research. The UK, through the Department for International Development, supports work in Bangladesh, India, Nepal, and Pakistan. Various donors have helped fund regional meetings of the Consortium. The World Bank contributes indirectly through its support for projects in the region.

**Support for Research with Farmers on Reduced and Zero Tillage:** In Nepal, farmer participatory research on the Chinese hand tractor involved staff of CIMMYT, of Nepal's National Wheat Research Program/Regional Agricultural Research Station at Bhairahawa, and of the Agricultural Engineering Division of the Nepal Agricultural Research Council (NARC), as well as the Agricultural District Office, Rupandehi; Lumbini Ground Water Project, Bhairahawa; and NECOS, a permaculture non-governmental organization based in Rupandehi District. Work in Bangladesh involved staff of CIMMYT and of the Wheat Research Centre of the Bangladesh Agricultural Research Institute.

rotovating the soil, sowing seed in rows, and planking—is remarkable to farmers and, in addition to reducing turnaround time, lessens tillage costs. Economic analyses in Nepal showed that, compared with traditional practices, the tractor decreased tillage and wheat sowing costs from Rs 2,650 to Rs 900, saving Rs 1,750 per hectare. "The tractor also diminishes the stoop labor inherent in current practices, something that pleases farmers enormously," Justice says.

Farmer groups in Nepal have found numerous and previously unsuspected uses for this technology: in wheat tillage and establishment; puddling soils for the rice crop; reaping rice; threshing wheat and rice; winnowing; pumping water; transporting farmyard manure to the field; carrying crops and milk to market; and preparing land for planting kidney beans and other higher value crops. "Nearly half the farmers who participated in testing would like to purchase a tractor," Justice says, "and three-quarters expressed interest in a communal purchase/use arrangement."

## Potential for Sustainable, Equitable Mechanization

"Farmers' interest and the data from this study could inform a larger program aimed at jump-starting Nepal into sustainable and socially equitable agricultural mechanization," says Peter Hobbs, wheat agronomist with CIMMYT's Natural Resources Group. Hobbs was first impressed with the potential of the hand tractor years ago during visits to China.

In Bangladesh, the hand tractor has already been widely adopted by farmers, but only as a rotovator. Meisner estimates that 200,000 Chinese tractors are now available to farmers in Bangladesh and the numbers are growing daily. "Growth in use has been phenomenal," says Meisner. "In 1990, no wheat farmers were using tractors. By 1994, over half were using the Chinese hand tractor. Every village has a mechanic and a workshop that can repair them." According to Meisner, growers like the tractors because the technology of the engine is simple, spare parts are easy to manufacture locally, and the tractor and attachments are cheap enough for farmers with little capital. "What is needed now in Bangladesh is the introduction and local manufacture of some of the hand tractor implements currently used in Nepal," Meisner says.

On the other hand, the rapid adoption of the Chinese tractor in Bangladesh needs to be replicated in Nepal, according to Justice and his counterparts in NARC's Agricultural Engineering Division and the National Wheat Research Program. "The government is presently looking into various ways to attain this, ranging from direct imports from China to local manufacture using Chinese and locally made components," he says. The Nepali research program has also engaged several local workshops and parts providers to furnish service, support, and tractor attachments. Import houses are being encouraged to import not only tractors but also attachments. Lastly, the project's small farmer cooperative approach has gained the interest of the Agricultural Development Bank of Nepal, which is considering this technology for use by the small-farmer cooperatives it supports.

## Surface Seeding: A Breakthrough

Equally promising for Nepal's rice–wheat farmers is the surface seeding technique, in which pre-soaked wheat seed is treated with farmyard manure (making it less appetizing to birds) and broadcast into a standing rice crop after the water has been drained but the soil is still saturated. "This is done with absolutely no tillage of any kind," Hobbs says. "When carried out properly, it results in excellent wheat stands. The wheat is planted on time and yields significantly better than wheat planted by traditional tillage methods." Hobbs credits Nepali agronomist, Ghana Shyam Giri, with bringing the technology from Bangladesh and perfecting it with Nepali farmers over the last five years. "The key is getting the right soil moisture at seeding," Hobbs says. "It is an excellent system for heavy, poorly drained soils in Nepal, which hinder farmers from preparing good seedbeds through tillage."

In on-farm and on-station experiments comparing wheat establishment methods in Nepal in 1993–94, surface seeding generated significantly higher yields and, by eliminating land preparation costs, higher profits. The system has the added advantage of not needing any tractor or accessory, and is thus suited to the farmers of least means. Nepal's Minister of Agriculture visited fields where this technology was being used or tested by farmers and praised scientists for developing such appropriate practices. Consortium partners are promoting the practice among farmers in Nepal, eastern India, and Bangladesh.

## Continued Studies on Natural Resources and Productivity

"Future research in rice–wheat systems of Nepal and elsewhere in Asia will focus on the longer-term implications of these new tillage systems on sustainability and productivity," Hobbs says. Among other things, he and his colleagues will examine effects on soil parameters (chemical, physical, and biological) and biotic factors (pests, weeds, and diseases) over time, both in farmers' fields and on experiment stations. "This is a long-term effort that will involve multidisciplinary teams working closely with farmers," he says.

Regarding mechanization, CIMMYT will work closely with national programs in the Consortium to scale up research on rice–wheat systems of the Indo-Gangetic plains. "Many machines and tools have been successful elsewhere in the world but have yet to be tested in the rice–wheat system," Justice says. "Previously, machine prototypes were tested, but testing alone could not ensure that farmers would use the machinery or that it would provide the solutions sought." Justice and his associates have applied a farmer participatory model for mechanization research so that they can avoid similar problems. "This model sets up an integrated partnership between small farmers, national researchers, and local workshops. We hope it will guide future work elsewhere to bring about mechanization in a way that is not only sustainable, but socially just."

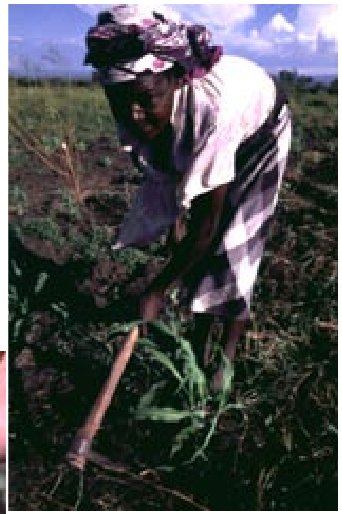
More Information: **l.harrington@cgiar.org**

# Genetic Counterspells against Witchweed

Struggling to grow a modest maize crop, Kenyan farmer Joseph Okelo contends with natural constraints ranging from drought to flooding, invisible viruses, and infertile soils. But the foe he dreads most is a small, ragged plant with delicate, purple flowers. This parasitic plant annually robs African grain producers of more than four million tons in yields. "**Striga has been a problem since time immemorial**," Okelo says. "Nowadays, farmers don't even try to control it, and infestation has worsened." **Does research offer any solutions?**

Also known as witchweed, *Striga* is amazingly prolific—a single plant can produce tens of thousands of pollen-like seeds that pepper the soil. Under the right conditions, a weed seed may latch onto a maize seedling, sapping nutrients and water, and otherwise arresting the host's development (the exact mechanism by which this occurs is not known). By the time the *Striga* plant breaks the soil surface, the worst damage to the host has already occurred, so farmers are understandably reluctant to spend hours in the hot sun weeding.

The scourge of *Striga* extends far beyond Joseph Okelo's plot in Kenya. It causes considerable yield losses throughout the seven agroecological zones of sub-Saharan Africa (excluding mountainous and forested areas) and has raised serious concern in southern Africa. Attesting to witchweed's deadly power, national research programs, centers of the Consultative Group on International Agricultural Research, universities in Europe and the United States, and major donors, most notably the Rockefeller Foundation, are waging a complex scientific war to curb its effects. Although a definitive solution has yet to appear in farmers' fields, researchers have increased their understanding of the pest and made notable strides towards overcoming the curse of witchweed over the past year.



**The weed *Striga* joins its roots and destiny in a lifelong marriage to its host. The back-breaking nature of weeding maize fields explains farmers' interest in alternative control technologies.**

## Fighting the "Poor Man's Pest"

"*Striga* is basically a poor man's pest," explains Joel Ransom, CIMMYT agronomist in eastern Africa who, in collaboration with staff of the Kenya Agricultural Research Institute (KARI), has spearheaded regional work to control the parasite. "It doesn't seem to like fertile, more biologically active soils, but thrives in the poor soils typical of small-scale maize systems in eastern Africa." According to Ransom, as intensified cropping, spurred by rising populations, has become more prevalent, so has *Striga*.

Ransom and his KARI counterparts have focused on varied management options, such as adding manures to fields, weeding *Striga* by hand before its seeds mature, rotating maize with non-susceptible "trap" crops to reduce *Striga* seed concentrations in soils, and generally ensuring that farm implements and maize seed are free of *Striga* seed or seed-bearing residues. Alone or in combination, these practices have worked well in experiments. But they are admittedly labor- and knowledge-intensive and so have met with limited acceptance among small-scale farmers.

In 1996, the Rockefeller Foundation put out a call for projects designed to combat *Striga* using molecular biology. In response, CIMMYT, KARI, and the International Institute of Tropical Agriculture (IITA), Nigeria, are collaborating under a newly funded and coordinated endeavor. Their diverse tactics for solving the *Striga* problem have a common focus on maize genetics. Each ultimately seeks to endow maize with traits, such as direct resistance to the parasite, that alone or in combination improve maize yields in *Striga*-infested fields. "This approach simplifies life for farmers who cannot use complex or costly management practices," Ransom says, "and it will provide a valuable complement where other control measures are practiced."

## Resistance from Wild Relatives

Encouraging results in *Striga* research over the years have come from IITA, particularly throught the efforts of scientists Jennifer Kling and Dana Berner. Now CIMMYT and IITA are searching within the diverse gene pool of maize—especially that portion associated with the crop's wild relatives, the grasses teosinte and *Tripsacum*—to identify *Striga*-resistance genes that can be transferred into productive tropical maize lines. Resistance appears to be present in both grasses. An IITA researcher, Admasu Melake-Berhan, who completed two months of biotechnology training at CIMMYT to gear up for this work, says that he and his colleagues have already crossed teosinte with maize and obtained near-maize types. "We'll develop genetic maps from these materials to reveal the number and location of the genes involved in *Striga* resistance," he says. Meanwhile, CIMMYT geneticist Daniel Grimanelli is following up with similar studies on *Tripsacum.* "It's a great resistance source," says Grimanelli, "although getting genes to maize from *Tripsacum* is much harder than from teosinte."

## Can "Jumping Genes" Create Resistance?

As for maize itself, breeders have searched for resistance to *Striga* in the crop for years without success. So Grimanelli and his colleagues at CIMMYT hit upon the idea of using biotechnology to modify maize, creating resistance. "When you go into a field in Africa, you encounter thousands of types of grasses, but no *Striga*," he says. "Resistance to *Striga* seems to be the general rule among the grasses. So there is something special about the species maize and sorghum—they must simply have the wrong alleles." Moreover, the biological trigger for *Striga* appears to be a simple substance emitted by the germinating maize seed. If the genetic mechanisms that control production of this substance in maize are simple, then they would presumably be easy to turn off, with no harmful effect to maize seedling development.

To accomplish this or produce other resistance-conferring mutations, the CIMMYT team is crossing normal maize with special genetic stocks containing "jumping genes"—genetic fragments that move spontaneously from one location on a chromosome to another, often modifying or deactivating genes. The researchers will then screen progeny of the crosses for resistance. "We are taking a chance here, but the approach is fairly inexpensive, and the benefits will be enormous if we succeed," Grimanelli says.

## A Faster Solution

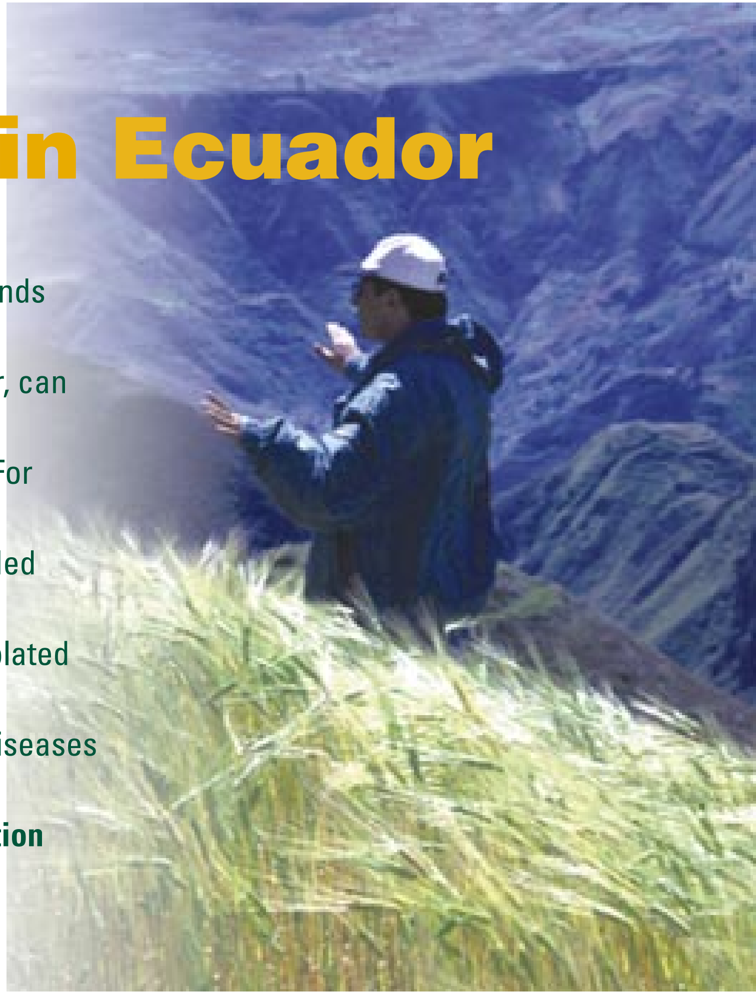
For the strategies just described, *at least several years* still separate today's laboratory and breeding research from tomorrow's resistant maize—a short span as science goes, but an eternity for *Striga*-plagued farmers. Another Rockefeller-funded research approach, however, could provide a faster solution. This technique involves coating the seed of herbicide-resistant maize with a small amount of herbicide. Once sown, the maize germinates normally but the herbicide kills any *Striga* seed in the vicinity. The method demonstrated impressive results in trials conducted in Kenya during the past year, and CIMMYT, KARI, and the Weizmann Institute in Israel are working with private companies that own the genes for herbicide-resistant maize to adapt this technology to African conditions and make it available to the continent's farmers. Collaborative studies by Jonathan Gressel of the Weizmann Institute and Fred Kanampiu of KARI have shown that, by treating maize seeds prior to planting, herbicide use is cut to a mere 30 grams per hectare. This rate puts the technology within reach of many of Africa's smallholder farmers, with minimal environmental impact.

"The *Striga* problem in Africa calls for an economical solution, and this is precisely what biotechnology and the judicious use of chemicals can offer," says Weizmann's Gressel, an unabashed proponent of the technology. "True," he concedes, "this technology may only be a stop-gap solution—the weeds could evolve resistance within several years—but it gives us a breather to find alternative approaches."

The major constraints to deployment of the practice appear to be legal and regulatory rather than scientific. The herbicides must be registered for use on maize in Kenya, and the issue of intellectual property rights must be resolved with the private-sector companies that hold the rights to the herbicide-resistance gene.

More Information: **d.grimanelli@cgiar.org**

# The Saraguro Barley Project in Ecuador



Ethnic farmers in Saraguro, a remote region in the highlands (2,700–3,500 meters above sea level) of southern Ecuador, can scarcely produce enough grain for the local population. For centuries, small grain cereals such as barley have provided most of the calories on which the inhabitants of these isolated mountain slopes subsist, but low-yielding varieties and diseases have kept grain production low. **A special barley production project is helping to revitalize Saraguro agriculture.**

Farmers who cultivate the hardscrabble soils in this region practice very rudimentary agriculture. They till the soil, sow the seed, and harvest their crops by hand or with draft animals. Local barley varieties are low yielding and highly susceptible to diseases, and farmers can never be sure how much grain they will harvest. They have little or no access to credit, improved seed, or agricultural extension services because of their geographical isolation. Consequently, yields are extremely low, averaging a mere 0.7 tons per hectare in the case of barley.

“Many times these hard-working farmers can’t produce enough to feed their families, especially when an epidemic flattens their barley crop, as stripe rust did in 1976,” says Hugo Vivar, barley breeder who coordinates the ICARDA/CIMMYT Barley Program for Latin America from his base in Mexico. “It’s clear they need outside help to better their yields and their lot in life.”

## Focus on Highland Farmers

Since 1995 Saragurans have had an exciting farming alternative that may gradually reach all producers in the region. That year, under Vivar’s leadership, the ICARDA/CIMMYT Barley Program, with Ecuador’s National Agricultural Research Institute (INIAP), initiated a barley production project targeting these small-scale farmers. Recalls Oswaldo Chicaiza, leader of INIAP’s Cereals Program, “We began working in Saraguro because it’s so far away from Quito, the capital city, where extension efforts are based. We figured if we could succeed here, we could succeed in other cereal-growing areas of the country where yields are low.”

The researchers offer farmers in Saraguro a technological package that includes seed of two disease resistant barley varieties and modest amounts of inputs; the project also facilitates the leasing of equipment for applying inputs and harvesting the crop. Most importantly for these remote mountain dwellers, all these components are provided to them at the farm gate.

“A key feature of the package is that it provides credit in kind, which means that inputs are given out without money changing hands. This makes inputs readily available to farmers who have no cash,” says Vivar. “Paying back their loans is usually no trouble after harvest.” The recovered funds go towards supporting farmer collaboration the following year.

The two barley varieties provided by the project are resistant to more than six diseases (including stripe rust) that periodically ravage barley in the area. One of these diseases, fusarium head scab, is caused by a fungus that produces toxins harmful to human and animal health. With the new resistant varieties, farmers can count on harvesting higher yields from year to year with the confidence that the grain they produce will not harm the people and animals that consume it.

## “Someone Has Come to Help Us”

The first year only one farmer agreed to participate in the project. He was amply rewarded for his courage: he produced two or three times more grain than his neighbors. Buoyed by his experience, 12 farmers signed up for the experiment the second year (1996). Many more wanted to join, but the project could support no more than 12 because it lacked funds. However, in 1997 the project was able to collect enough money to support participation by 240 producers, partly because of the farmers’ high rate of loan repayment (more than 98%). Their exceptional yields—two to five times higher than the national average—drew 500 growers in 1998.

But beyond these impressive numbers, the project is making a big difference in the lives of farmers. “I used to get four sackfuls of grain per hectare before I joined the project,” relates Hilda Jaramillo, a farmer with two years’ involvement in the project. “Now I harvest 18 sackfuls, which provides enough food for me and my family for a whole year.” Says a leading farmer from a village close to Saraguro, “We’re happy because my son doesn’t have to work in the gold mines anymore to bring in more money. Mining is very hard work, and he used to get sick all the time.” Another farmer simply says, “This is the first time someone has come to help us.”

## New Barley Varieties and New Markets

The barley commonly grown in this region is hulled—that is, the grain is covered by a seedcoat that must be removed before cooking. Women feed their families a variety of dishes made from barley, but hulling the grain is a tedious, time-consuming chore. “One of the varieties being distributed through the project is Atahualpa, a hull-less barley. Women really like it because they don’t have to grind and sieve the grain to get rid of the hull before cooking,” comments Chicaiza.

The surge in Saraguro’s barley harvests comes at a time when a market for barley food products is emerging in Ecuador’s metropolitan areas. “In the past, you’d never find toasted barley flour or barley ‘rice’ in an urban supermarket,” explains Vivar. “But people who have migrated to the cities from rural areas have created a demand for barley products. They’re cheaper and more familiar to them than, say, wheat bread or oatmeal.” Though Saraguro is far from Quito, it is within 200 km of two fairly large cities. Farmers who produce more barley than they can consume will be able to market the surplus to bring in extra cash.

## Future Expansion

The benefits generated in Saraguro have raised the spirits—and the expectations—of farmers in nearby villages. Many who have not yet managed to join the project are eager to do so next year, which puts pressure on the project’s limited resources. In the future it is expected that farmers with several years’ involvement will be able to buy seed and other inputs with their own savings, freeing up funds to bring new farmers into the project.

Training, both of farmers and of INIAP staff, is essential to the project’s success and continuation. Farmers must be taught new agronomic practices to get the most out of modern barley varieties, and INIAP staff need training to manage and implement the project effectively. Given the limited number of INIAP workers in the region, training the farmers themselves to do extension work is seen as a way of supplementing their efforts. Thus in 1996, three young farmers underwent specialized training at INIAP’s Santa Catalina Experiment Station. After a one-week course, they have continued to “learn by doing” as they work as paid technicians under the supervision of INIAP staff.

An added bonus of the project is that Saraguro farmers are now aware of the benefits they can garner from modern, disease resistant crop varieties and the new agronomic practices that go with them. They are starting to plant improved seed of other crops such as potatoes, peas, wheat, triticale, and maize, which will diversify their production systems and make them more sustainable and profitable. Vivar and Chicaiza are delighted with this development, since it is in keeping with the project’s goal of improving not only barley yields but also the general well-being of people in the highlands.

More Information: **h.vivar@cgiar.org**

# Crop Management Research Training: Empowering Agronomists in Sub-Saharan Africa

Crop management researchers and extensionists have **a crucial role in generating improved technologies for farmers in developing countries**. Yet the degree programs from which these specialists emerge are often highly theoretical, rarely imparting the interdisciplinary approaches and practical skills needed to design, test, and promote relevant crop management practices.

**Zimbabwean agronomist Alexious Makanganise attended the regional crop management training course in Kenya in 1995 and studies tillage and fertility interactions in communal area farms back home. He is extremely positive about his experience in Kenya. "This is a very fruitful course," Makanganise says. "It is so important to be able to identify the problems farmers face, propose solutions, and do the research to develop and test them."**

To help fill this gap for agronomists and extension workers in eastern, central, and southern Africa—where farmers desperately need new, productivity-enhancing, resource-conserving technology—in 1991, the Kenya Agricultural Research Institute (KARI), Egerton University, and CIMMYT launched a regional crop management research training (CMRT) course that would enable participants to acquire such knowledge rapidly and apply it immediately upon returning home.*

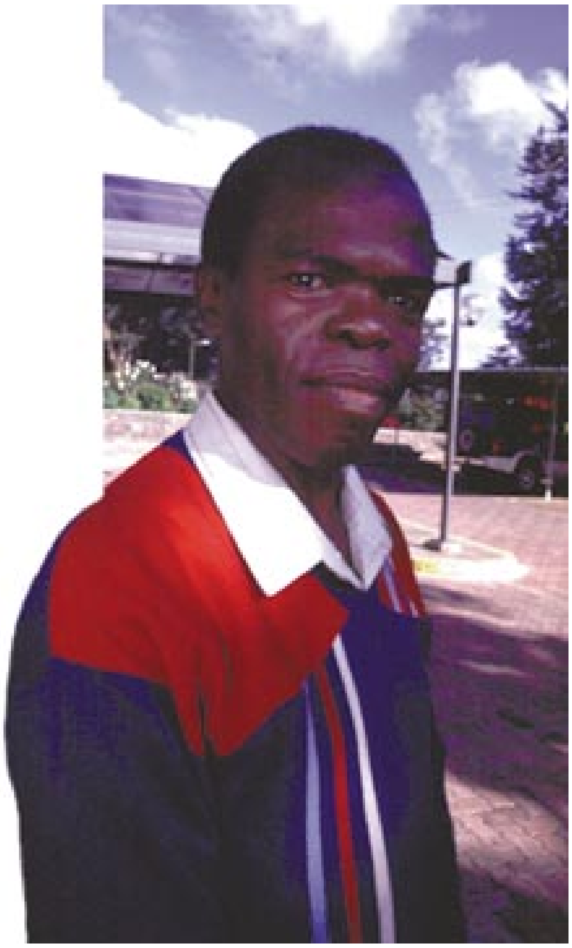
Offered at the Egerton campus in Njoro, Kenya, the six-month, in-service course combines equal measures of field and classroom time to develop skills ranging from field plot techniques and scientific report writing to economic analysis, with a focus on farming systems that involve maize, beans, wheat, or teff, the region's common food crops. Since its inception, the course has evolved in response to suggestions from participants, among other things adding a seed technology component, a gender focus, more practice in data management and computing, and increased exposure to farmer-researcher interactions. One important recent enhancement has been to familiarize course members with the principles and practical issues of a farmer participatory approach (participatory rural appraisal, or PRA), by applying it to identify production problems. "The idea is to empower farmers—they talk, and we listen," says Robert Obura, CMRT director. "Farmers have certain ways of doing things that, when we walk away with only a survey, we never really understand."

---

* **Training was made possible through initial funding from the Canadian International Development Agency and subsequent support from the US Agency for International Development.**

## Evidence of Impact

Empowerment of a different kind was the idea behind a major follow-up study by Obura and his team of instructors in 1997 to assess the course's impacts on its more than 150 alumni. A regionally representative selection of the graduates received a questionnaire concerning the relevance of course topics, the quality of presentation, and the level of detail covered. The instructors then went out personally to collect the questionnaires and interview the former participants and their supervisors. "The common message was that the course graduates were more effective, better able to interact with peers, and were consulted on issues where their expertise had not previously been sought," says Maurice Shiluli, a KARI economist and CMRT instructor (pictured here).



## Maintaining Momentum in Regional Crop Management Training

In addition to its centerpiece CMRT course, the Njoro facility also offers short courses on a range of topics and provides conference services—successful sidelines that constitute key sources of operating funds, according to Obura. "Funding is a major concern these days," he says. "It is increasingly difficult to obtain fellowships for researchers to attend the CMRT course."

"The CIMMYT Maize Program was instrumental in establishing the center in the early 1990s and has provided significant financial, administrative, and technical support since then," says CIMMYT maize agronomist in Kenya, Joel Ransom, citing the direct involvement for several years of CIMMYT researcher A.F.E. Palmer. "There is no other course like this in Africa, and few elsewhere. What makes it different is the regional focus, the quality and scope of the curriculum, and the experience of the instructors, most of whom have been on board from the beginning."

CIMMYT has also helped establish and support regional CMRT courses for Asia (in Bangkok, Thailand) and for Latin America and Portuguese-speaking Africa (operated by the Brazilian Agricultural Research Enterprise, EMBRAPA, at Sete Lagoas, Minas Gerais, Brazil).

More Information: **d.friesen@cgiar.org**

# Secrets in the Seed

# Opening Gene Bank Doors a Little Wider

Plant breeders looking to use gene banks in their pursuit of valued agricultural traits face a formidable dilemma. Given that crop accessions in a collection can number in the tens of thousands, how much time, effort, and money applied to a search can be justified by the cause? With little empirical information at hand, scientists lack the tools for making strategic decisions that could shorten or extend their efforts by years, with very real repercussions for smallholder farmers facing a new pest or disease. Now, **thanks to recent analysis and modeling work by CIMMYT, researchers have the methodological key for efficiently unlocking the potential of gene banks for crop improvement.**

A 1998 study, "Optimal Search in *Ex Situ* Collections of Wheat Genetic Resources," conducted by CIMMYT economist Melinda Smale, affiliate economist Douglas Gollin of Williams College, and the head of wheat genetic resources, Bent Skovmand, puts forward an empirical search model for analyzing gene bank management decisions and in the process underscores the value and usefulness of these repositories for the world's major cereal crops.

Several issues prompted Smale and her colleagues to undertake the study. In these days of tight budgets and cost consciousness, it makes sense to tackle tough economic questions bearing on the value of genetic resource collections and the costs/benefits of searching them. A prototype of an optimal search model, a major element of the study, could lay the foundation for the development of management tools to increase the efficient use of gene banks. Finally, the study sought to address pertinent points raised by critics of *ex situ* collections (seeds or other propagative materials preserved in collections separate from their environment of origin).

"Some critics in the field of evolutionary biology have referred to gene banks as 'seed morgues,' charging that they are wasteful—that they 'freeze' evolution at the moment of collection—and may limit ability to adapt," says Smale. To economists, meanwhile, seed stored unused in banks resembles a factory with excess capacity. This implies that additional accessions have no value.

"What we found," Smale adds, "is that a low frequency of direct requests to the gene bank does not imply that accessions have no value. Even if the bank is used only on rare occasions, large collections can have payoffs over the long term."

## In Searches, the Big Question Is, "How Much Is Enough?"

How Much Is Enough?

In investigating the economics of gene bank utilization, the researchers focused on three questions. First, when do large collections have value? Second, what is the value of specialized knowledge about the distribution of desirable traits across types of germplasm? In this case, they computed the value of knowing that resistance to Russian wheat aphid is more common among a set of bread wheat landraces from Iran than among the general population of bread wheats. Third, under what conditions should more than one type of material be searched? The cost of evaluating and transferring resistance to septoria tritici leaf blotch from conventional breeding lines and emmer wheats was investigated for this last question.

To get at the heart of these matters, the researchers developed a theoretical model for analyzing the gene bank management decisions that are made when searching for traits of economic value in *ex situ* collections of wheat. The model had to account for a range of variables and factors affecting the benefits to be gained from locating a desired trait (such as disease resistance or tolerance) and the costs involved in searches of different types of germplasm. Costs and benefits are heavily influenced by the time lags associated with transferring the trait, breeding, and adoption by farmers. Of critical importance is the probability distribution for the trait—or, more simply, the likelihood of finding what you are looking for in the type of germplasm being searched.

This last factor is one on which proponents and detractors of gene banks differ considerably in their assumptions and, consequently, their conclusions. Gollin illustrates this difference with the following contrasting examples. Suppose that a desirable trait is found with some distribution within a particular population and that it is equally advantageous wherever it is found. For example, assume we are seeking flowers that are yellow and that any shade of the color is equally useful. In this case, there is perfect substitutability among the subpopulation of species that possesses the trait (all yellow flowers), and zero substitutability with the remainder of the population. Once a single yellow flower is found, however, all further search becomes redundant. This is one of the underlying assumptions of those challenging the need for large *ex situ* collections.

Alternatively, suppose that the desired trait can be found in varying intensities or forms, so that it can be conceptualized as a continuous variable. For example, gold might be found in different deposits of ore at varying degrees of concentration, or a number of different plants might have disease resistance properties of varying usefulness. In this case, there is imperfect substitutability among materials in the population. Different materials are more or less desirable—a distribution of "desirability" is found across the population. Additional searching will always be expected to offer some marginal benefit unless an extreme value has been obtained. This scenario supports the need for larger collections, as do several actual cases in which searches through large collections were required to locate a rare trait simply not found anywhere else. Resistance to Russian wheat aphid was one such case.

## The Bottom Line

An essential conclusion of this study, say the authors, is that “the optimal scale of a search is very sensitive to the size of the economic problem, the costs of search technology, as well as the probability distribution of the trait.” For some traits, the payoffs are simply not large enough to justify exhaustive searches. For other traits, the probability of finding the right germplasm warrants a small search, and there are occasional cases when a large search will be justified.

“As intuition would tell us, large collections have value when the trait is rare and the problem is of economic consequence,” Smale continues. “It is evident through the application of the model that infrequent requests for searches at the bank in no way imply that additional accessions are valueless. Some accessions may sit ‘unused’ for years, only to be called on when a need for that specific trait emerges.”

Because of the time lags associated with locating and transferring desired traits from distant populations to host varieties and getting them adopted in the field, Gollin explains, it is rational to turn to unimproved materials only after breeding lines have been searched extensively and the problem is large. However, though collections of landraces may be used only infrequently given current search and transfer techniques, when they are used, high values are associated with those occasions.

Once into the study, the nature of the work prompted the scientists to reexamine what is meant by the ubiquitous term “utilization.” Noting that “utilization” often connotes breeding activities alone, the authors contend that, in reality, gene banks also respond to a number of requests for materials used in biochemical, molecular, and genetic research, and also may contribute to the overall accumulation of scientific knowledge.

## Putting Research Results to Work

As with much CIMMYT economics research, this study paves the way for more in-depth work. The authors foresee additional research aimed at valuing accessions and determining the optimal size of an *ex situ* collection, and they have good reason to be optimistic. A recent study commissioned by the Systemwide Genetic Resources Program of the Consultative Group on International Agricultural Research, to which Skovmand and Suketoshi Taba (head of maize genetic resources at CIMMYT) have contributed, has developed estimates of the actual costs of gene bank operations. This dovetails with the optimal search study and will provide data for ultimately procuring the valuations needed for informed management decisions.

Further inquiries into valuation will explore the value of gene banks as a defense against doomsday scenarios, or as Gollin and Smale put it, “how much it is worth spending on gene banks as insurance against cataclysmic disasters.”

An important output envisioned by the scientists is a set of practical management guidelines for gene bank managers in national programs. The research has already been discussed with the International Plant Genetic Resources Institute, and the search model has been used informally as an instructive vehicle.

Many see bright prospects emerging for plant breeders as scientists become more adept at using the tools offered by biotechnology to expedite searches in *ex situ* collections, thereby opening access to materials that were previously too expensive to find and use. This study is a modest but necessary step toward that goal.

“The model is an instrument that can be readily modified to accommodate the increased use of advanced technologies,“ declares Skovmand. “DNA fingerprinting and marker-assisted selection, by helping us characterize materials more rapidly, can make searches quicker and reduce the overall time of transfer,” he says. “If you can get at what’s in a landrace or wild relative quickly, then the time factor and the costs associated with it collapse dramatically.”

More Information: **m.smale@cgiar.org**
**b.skovmand@cgiar.org**

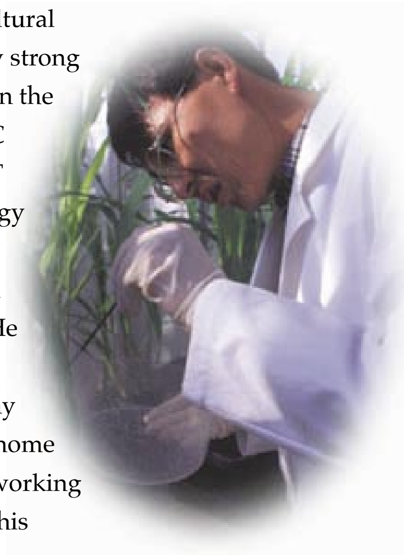
# Biotech Training
## Makes a World of Difference to National Programs

A fundamental goal of CIMMYT's Applied Biotechnology Center (ABC) is to bridge the gap between advanced research in the industrialized world and applied breeding in the developing world. The ABC responds to the challenge by **training and empowering scientists from national research programs to use biotechnology's tools** to address agricultural problems in their home countries and regions. The sessions also promote bonds among researchers and with CIMMYT that later serve to backstop and advance crop improvement efforts worldwide.

"There continues to be increased interest in training in biotechnology by national programs and I don't see that decreasing," says ABC director David Hoisington. "As CIMMYT expands its activities in biotechnology, so do the national programs, and the first thing they need is guidance and training to get off the ground. I think they'll be looking to the CGIAR centers as one of the best options for that."

Hoisington's words rang true for 16 participants from 11 developing nations who attended ABC's 1998 workshop on Genetic Engineering of Maize and Wheat.* A common thread ran among the scientists: they all wished to begin applying the knowledge and experience they gained at the workshop to either planned or current programs in their home countries. Their diverse foci, ranging from micro- to mega-level projects, converged on one point—the applicable.

### Tale of Two Participants



Guoying Wang, associate professor in the Department of Biotechnology at China Agricultural University, drew strong parallels between the structure of ABC within CIMMYT and biotechnology units within China's research establishment. He intended to use some of the many lessons he took home to improve the working relationships in his institution.

Maria José Vilaca de Vasconcelos, coordinator for the Brazilian Agricultural Research Enterprise's (EMBRAPA's) maize transformation program, had more specific hands-on expectations for the course. Although her lab has 500 strains of *Bacillus thuringiensis* (*Bt*), a natural insecticide, only 19 work against *Spodoptera frugiperda*, commonly known as the fall armyworm, the most important insect pest threatening Brazilian maize. By enhancing her knowledge and

---

*** The Workshop on Genetic Engineering of Maize and Wheat was sponsored by the United Nations Development Programme (UNDP), the Swiss Center for International Agriculture (ZIL/DEZA), the Swiss Institute of Technology (ETH), and CIMMYT.**

background in agrobacterium and biolistic transformation techniques, which are used to introduce new genes into host materials (in this instance, *Bt* into maize germplasm), she hopes to accelerate production of maize lines with effective resistance to *S. frugiperda*.

Natasha Bohorova, coordinator of the Genetic Engineering workshop, was heartened after coming upon a poster produced by Vasconcelos and her colleagues at a recent international biotech conference. "They presented a transient expression of reporter genes introduced into maize via biolistic and agrobacterium transformation. That means that they are using the techniques successfully, which stems directly from the workshop here."

## The Impetus to Innovate

While participants from some well-established programs were looking for that one technique or piece of knowledge required to keep their efforts moving forward, others hoped to acquire a sound grounding in the basic building blocks of transformation to get their work underway. One such participant, Sami Reda Saber Sabry, Senior Wheat Researcher at Egypt's Field Crops Research Institute, had undertaken some transformation work with tissue culture on his own initiative but with little success. As he was leaving for the workshop, some new equipment was just arriving, and he hoped that soon he would be renovating not just his lab, but his program.

"The course provided exactly what I was looking for," said Sabry, "as far as working with my hands and seeing with my eyes. There's a lot of art involved with tissue culture aside from the science. The basic science you can find everywhere—in books, in papers, on the Internet—but what I was looking for was the techniques. Based on what I learned here I'm going to launch completely new work."

Sabry has maintained contact with CIMMYT, says Bohorova, and the latest word was that he had applied the protocols provided by CIMMYT. It is too soon to judge if significant results will be obtained, she says, but "this time as compared to unsuccessful past efforts, he has embryonic calli coming on, so that's certainly a good sign."

"The workshops are useful for participants in two respects," Bohorova points out. "First, quite naturally, the scientists learn how to manipulate and use the technologies that biotech has to offer. Second, they become well acquainted with biosafety, intellectual property rights, and other issues related to using genetically engineered products and incorporating them into national programs." The impact of such workshops often extends past the course term as Bohorova keeps in touch with many participants, and the CIMMYT protocols used for the workshops have been adopted in part or in their entirety by a number of countries, including China, India, Egypt, and Morocco.

Conducting workshops for scientists from developing nations is an important function of the ABC, but workshops are only one approach to putting biotech to work in farmers' fields. During the past year, the ABC took a fresh look at its training strategy and goals, and responded by launching a dynamic new initiative, the Asian Maize Biotechnology Network (see "AMBIONET," p. 30) and an innovative in-house biotech course (see box, next page).

More Information:
**d.hoisington@cgiar.org**
**n.bohorova@cgiar.org**

# In-House Workshop Helps CIMMYT Extend Biotech to the World

In December 1997, CIMMYT's Applied Biotechnology Center (ABC) conducted a two-week workshop, "Biotechnology Applications to Plant Breeding." Like past workshops, it had a diverse assemblage of nationalities, levels of expertise, and specialization, and CIMMYT's Director General was on hand to welcome the participants. But participants and presenters exhibited an unusual camaraderie, usually seen on the closing, not the opening, day of such courses. Perhaps it was because the attendees were all CIMMYT staff.

## Workshop Origins

"The ABC developed CIMMYT's first-ever 'internal' workshop to respond to a general feeling among staff that they would like to know more about the basic techniques of biotechnology," says David Hoisington, ABC director. "In fact, we had CIMMYT scientists applying to courses that we offered to national programs," he confides, adding that such indicators prompted his program to develop a workshop, based on responses from a Center-wide questionnaire, that was more appropriate to CIMMYT's needs and scientists.

The workshop had two objectives. The first was to encourage CIMMYT staff to learn and acquire a better appreciation of particular applications of biotechnology for maize and wheat improvement. The second was to create an opportunity for staff to interact and develop stronger collaboration, especially in view of the Center's emphasis on project-based teams.

## Workshop Results: Some Personal Perspectives

"The course was a watershed towards the integration of maize breeding efforts and biotechnology," declares maize physiologist Gregory Edmeades. "It was a major coup for ABC to make this technology possible, do-able, and attractive to maize breeders," he says, pointing out that though few scientists would openly admit it, many may have felt a bit "intimidated" by the procedures and processes. "As the technology was explained and taught carefully as a series of steps, I think we all became a bit more confident and open to its use. Breeding is going this way whether we like it or not."

Edmeades has already observed some positive effects from the workshop, noting that it stimulated an abundance of good discussions among the breeders and led to a full conference between the Maize Program and the ABC, which focused on support and collaborations on breeding efforts.

Wheat pathologist Ravi Singh echoed Edmeades on several points. Having worked with the ABC on diverse projects over the years, he says many of the principles and potentials of the technology were already familiar, but the workshop gave him a new perspective on the complex lab processes and the molecular-level mechanisms behind the biotech acronyms.

"Equally important," Singh adds, "was the opportunity to interact and exchange ideas with people at CIMMYT. I've been here 14 years, and though I knew many people at the sessions personally, there were many I didn't know. Convening this group in this forum was an invaluable aspect of the workshop."

For Hoisington the workshop provided benefits to ABC as well as to workshop participants. "There is now much more acceptance of biotechnology across CIMMYT," he observes, "and it is a key component of CIMMYT's activities." Although he is reluctant to attribute this sea change to the workshop, he will credit the sessions for giving rise to some exciting new synergies. "We're seeing strong interest in getting people together to look at common problems of maize and wheat and how, together, we can solve them. That's good for CIMMYT and, more importantly, good for the national programs and farmers who eventually reap the benefits of the collaborations."

# AMBIONET: A Different Approach to Technology Transfer

"AMBIONET is a different approach to technology transfer and training than any we've taken before," comments David Hoisington, director of CIMMYT's Applied Biotechnology Center (ABC). AMBIONET—the Asian Maize Biotechnology Network—got off the ground last April with a planning meeting in Thailand. Co-financed by the Asian Development Bank (ADB), CIMMYT, and the national research systems of partner countries, **the network focuses on the application of biotechnology to improve maize in Asia.**

AMBIONET's stated goal is to "increase maize productivity in the partner countries through the development via molecular genetics of improved cultivars with high yield potential, combined with durable resistance to pests and diseases and tolerance for abiotic stresses." This will be accomplished by enhancing partner countries' capacity to adopt biotechnology tools for maize improvement and through cooperative efforts using molecular genetics to improve specific traits in maize.

## Strength in Numbers, Strength in Research

By establishing a collaborative research and training network, national maize and biotechnology programs should greatly enhance the effectiveness and impact of their efforts. Farmers throughout the region will have access to the results of network collaboration—as opposed to lesser achievements that frequently extend no farther than a country's borders.

"In numbers there is strength," goes the maxim, which aptly applies to AMBIONET. The network's five partner countries—India, China, Indonesia, the Philippines, and Thailand—have significant biotechnology efforts underway. CIMMYT, the sixth partner, will play an essential role in AMBIONET's training component, focusing on breeding, field evaluations, and biotechnology processes and techniques. The Center will also backstop national and regional efforts by providing biotech products and germplasm.

"In this case, we're not looking at establishing technologies," Hoisington explains. "We're looking at building on existing capabilities, developed to a considerable extent by the Rice Biotechnology Network, funded by the Asian Development Bank. We can take that capacity and work very effectively on the problems of maize that are specific to the region."

Knowledge and materials will be shared throughout the network. With each partner country willing and able to contribute research efforts and results to larger projects, progress can be stimulated and quickened when tasks are divided up among national programs. Member countries can also take advantage of discoveries and materials generated by labs in other countries to advance their own work.

## New Biotech Training Options

Complementing the network's diffused system for disseminating information and materials is its decentralized, shared approach to training. Most ABC biotech training has taken place at CIMMYT headquarters in Mexico to make use of the Center's first-class laboratories. But as network countries have expanded their own biotech facilities and capabilities, new options for training have appeared.

"We want to take advantage of what each country has to offer," says Hoisington, adding that those "offerings" go beyond labs and facilities to highly qualified personnel. CIMMYT will train national scientists to work as trainers for the workshops, he explains. Except for the initial training in Mexico, workshops will be held in the labs of AMBIONET countries, significantly expanding CIMMYT/AMBIONET training capabilities and options.

Maria Luz George, AMBIONET's recently appointed project coordinator, pictured above, will serve as the principal link between CIMMYT and the partner nations, picking up new technologies at headquarters and then coordinating appropriate training activities at the national, multinational, or regional level, depending on need. She will also actively convey the needs and training opportunities in the region back to headquarters, troubleshoot problems, visit labs regularly, and serve as a catalyst to keep individual projects moving.

Artemio Salazar, professor and maize breeder at the Philippines' Institute for Plant Breeding, is looking forward to working with the coordinator and network collaborators. "For maize, this is the first truly regional effort among breeders and geneticists," says Salazar. "At the intra-country level, interaction among this group has been somewhat limited, and even more so among maize researchers across countries. This project offers the historic opportunity to prove that we can work together for our mutual benefit. Given the strong organizational, financial, and technical support, I fully expect something concrete to come out of this effort."

## Other Benefits for Network Members

Though immersed in the exigencies of getting the project underway, Hoisington took time for some mild speculation on AMBIONET's long-term possibilities and the benefits it might offer its partners.

"Looking long term at how CIMMYT can meet its needs in biotech, particularly in the realm of molecular markers, I believe that good, strong biotech programs at the national level could help ease the burden on our biotech lab here in Mexico," he says. "Establishing dynamic and vigorous ties with such programs and institutes, both in Asia through AMBIONET, and in Africa through CIMMYT's Kenya/Zimbabwe program, builds our capacity to advance technologies that then feed back to clients around the world."

Citing the hard realities of project funding, Hoisington believes that partnerships such as AMBIONET can help provide some much-needed stability and sustainability for activities in the national labs.

"A project pumps money into an activity or an institute," says Hoisington, "but when that project terminates, there's a probability the activities will cease for lack of funds. If a collaboration is built so that CIMMYT, if it wishes, can step in and invest in national programs' marker technologies for our own needs, it should help create a more sustainable system at the national program level. The network implies that we now have a vested interest in making sure that the national labs put out quality work and ensuring the quality of the labs themselves."

One fairly safe bet, however, is that the ranks of AMBIONET will grow to include more Asian maize-producing countries—in the process extending both the benefits and the capabilities of the network.

More Information: **m.george@cgiar.org**

# Geneticists' Hunch Results in Higher Wheat Yields

For well over a decade, doomsayers have predicted that further increases in wheat yields will prove impossible to attain. We report that all is well on the yield frontier. Several years of testing have confirmed that on average **the CIMMYT Wheat Program's newest breeding lines yield a generous 5–8% more than commercial varieties** currently available.

As one would expect, CIMMYT breeders pursue several strategies as they attempt to raise wheat's yield potential and productivity. They have long recognized that good science depends on more than a formulaic approach to a problem. A willingness to research some of the more unusual ideas is also critical to success.

One such idea has produced exceptional results. For the past eight years, CIMMYT wheat scientists have tested a hypothesized link between higher yield and a chromosome segment from wheat grass (*Agropyron elongatum*) that carries the leaf rust resistance gene *Lr19*. Geneticist Ravi Singh first started to think that there might be a connection between yield and the *A. elongatum* chromosome segment when he observed a new rust-resistant cultivar, Oasis, which had been released in northwestern Mexico in 1986.

Tested under disease-free conditions, Oasis yielded more than its parent, Yecora, released in 1970.* As Singh points out, it is not uncommon for yields of new lines to exceed those of old lines—that is one objective of breeding—but the curious circumstance here was that Oasis and Yecora were closely related, so their difference in yield potential was unexpected. Oasis was derived from Yecora through a process called backcrossing, which produces new lines of wheat that are very similar to the original variety. The new lines express most of the original variety's traits but are enriched with one new trait from the donor parent. In Oasis, the donor parent was a Canadian line called Agatha. Agatha carried *Lr19*, a major leaf rust resistance gene, on a small piece of chromosome from *A. elongatum* that had been translocated into the wheat chromosome—known as the 7DL.7Ag translocation.

Oasis' surprising yield first became apparent in trials designed to study losses from heavy leaf rust infection. Yecora and Oasis were considered ideal for such a study, because the only difference between the two cultivars was assumed to be the translocated chromosome segment that made Oasis resistant to leaf rust, unlike Yecora. As part of the experiment, researchers grew both cultivars in the absence of rust to get a clear estimate of yield potential. It was then that they noticed the yield superiority of Oasis.

## Hypothesis Confirmed

Singh, along with Sanjaya Rajaram (now director of the Wheat Program, but then the head of bread wheat breeding) and coworkers, decided to investigate this unusual result. Two research teams were formed; each would test the effect of the 7DL.7Ag translocation in a number of high yielding cultivars. Researchers decided to conduct more than one study because they wanted to obtain more reliable results.

The yield evaluations lasted for four years and revealed that the yield increment shown by Oasis was not a simple coincidence. Both research teams developed lines that showed marked progress in yield over the parent cultivars. Lines with the 7DL.7Ag translocation consistently yielded 5–8% more than the best available lines. The greatest yield advances in any one year ranged from 17% to 26% over the commercial variety Bacanora, released in 1988, with one line yielding more than 10 tons per hectare. Given that an advance in yield of 0.5–1.0% per year is the breeders' benchmark for a "normal" rate of yield improvement, this increment equals at least ten years' worth of breeding. The new lines are available to collaborators through CIMMYT's international nursery system.

This yield breakthrough underscores the fact that breeding is a long-term process that builds on the efforts of many people, not just the breeding teams mentioned here. "The *A. elongatum* chromosome segment was translocated into the wheat genome in Canada in the mid-1960s by Sharma and Knott," says Singh.** Ricardo Rodríguez, a scientist who is now retired from CIMMYT, developed Oasis by backcrossing the *A. elongatum* segment into Yecora.

Work on Oasis also shows how hunches based on years of experience can lead to research that is both novel and fruitful. "At CIMMYT we have been fortunate to explore new research approaches as they have presented themselves," says Maarten van Ginkel, head of the bread wheat program. "We hope to continue to take full advantage of unusual ideas that may produce large payoffs." The link between yield

* Singh, R.P., T.S. Payne, P. Figueroa, and S. Valenzuela. 1991. Comparison of the effect of leaf rust on the grain yield of resistant, partially resistant, and susceptible spring wheat cultivars. *American Journal of Alternative Agriculture* 6: 115-121.

** Sharma, D., and D.R. Knott. 1966. The transfer of leaf-rust resistance from *Agropyron* to *Triticum* by irradiation. *Can. J. Genet. Cytol.* 8:137-143.

and the *A. elongatum* segment—fully documented in *Crop Science****—is only one such idea. "Many additional treasures may still be hidden in wild grasses like *Agropyron*," comments van Ginkel.

## No Limits on Innovation

CIMMYT breeders remain intent on streamlining the breeding process and welcome new applications, such as advances in genetics, physiology, crop modeling, and biotechnology, that make this possible. Van Ginkel points out that one frustrating aspect of breeding research is that it still requires large numbers of painstaking crosses, of which only a few result in suitable germplasm. "In the past, we benefited from the flexibility to study large populations from many crosses," he says. "Presently we need to become more efficient with our resources."

For van Ginkel and his colleagues, "becoming more efficient" means developing a breeding methodology that is increasingly gene-based rather than based largely on probability, although probability will always play a role. "Simulation and modeling of genetic rules may allow us to target our crosses better," says van Ginkel. "New avenues such as doubled haploids and marker-assisted selection will also help us achieve greater efficiency."

"The tendency of people at each stage of our history to believe we have reached the limit has applied to wheat yields no less than to other parameters of advance," observed Lloyd Evans, chief research scientist with the Commonwealth Scientific and Industrial Research Organization, in 1986, the year Oasis was released. The subsequent and unexpected contribution of Oasis to researchers' efforts to break the yield barrier shows that the limits of innovation in wheat breeding have not been reached—at least not at CIMMYT.

More Information: **m.vginkel@cgiar.org**
**r.singh@cgiar.org**

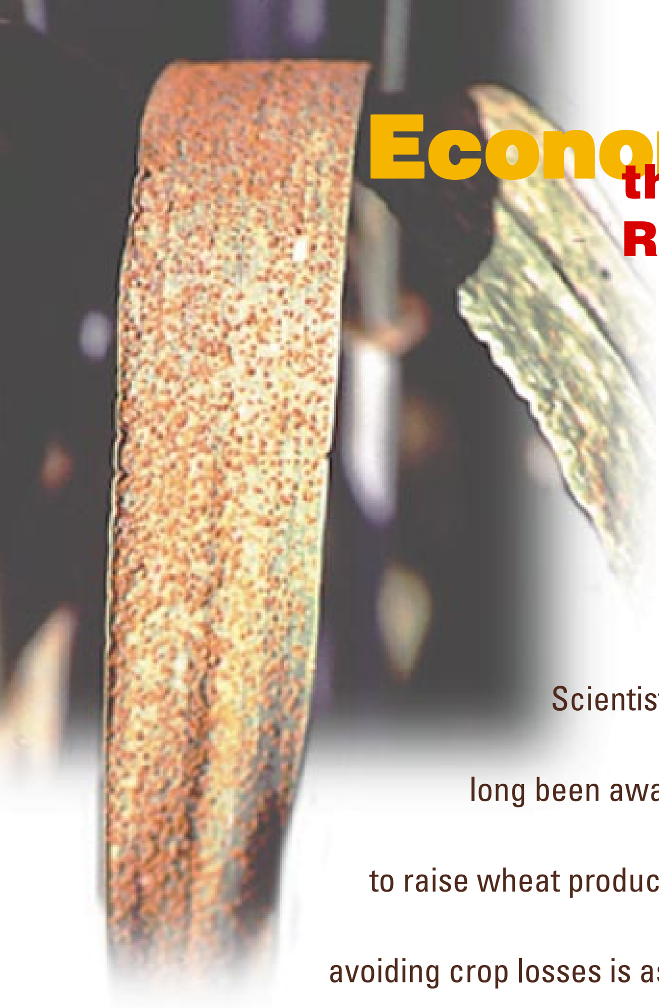
*** **Singh, R.P., J. Huerta-Espino, S. Rajaram, and J, Crossa. 1998. Agronomic effects from chromosome translocations 7DL.7Ag and 1BL.1RS in spring wheat. *Crop Science* 38: 27-33.**

# Technology and the Test of Time

Change for the Better

Change for the Better

Change for the Better



# Economists Confirm the Impact of CIMMYT's Rust Resistance Research

Scientists have long been aware that to raise wheat productivity, avoiding crop losses is as crucial as improving wheat's yielding capacity. No matter what heights farmers' yields *might* reach, it is all for naught if a disease epidemic devastates their fields. In wheat, no other disease poses such a threat as the three forms of rust—stem, leaf, and yellow rust—with their potential to cause calamitous crop losses. **Almost 30 years ago, CIMMYT adopted an unusual strategy to breed wheats that were resistant to leaf rust.** New evidence shows how this strategy has translated into an upturn in farmers' harvests, incomes, and health.

"An improved wheat variety does farmers no good if it is at the mercy of disease epidemics," points out pathologist Jesse Dubin, associate director of CIMMYT's Wheat Program. "They need to protect their wheat crops, especially from the rusts, and genetic resistance is the best way to do that." Since genetic disease resistance is integrated into the seed, it affords the farmer protection at little expense. By doing away with the need to apply fungicides, genetic resistance reduces production costs and has no ill effects on the environment.

Economist Melinda Smale and wheat pathologist Ravi Singh recently conducted a CIMMYT study on the economic benefits of incorporating leaf rust resistance into modern spring bread wheats. The objective of the study, which used data from the irrigated Yaqui Valley in northwestern Mexico, was to estimate the economic benefits of CIMMYT's decision—taken 28 years ago—to incorporate so-called "nonspecific" leaf rust resistance into its bread wheats.

Using extremely conservative assumptions, Smale and Singh estimated that the **gross benefits generated between 1970 and 1990 through CIMMYT's strategy for incorporating nonspecific disease resistance into wheat in the Yaqui Valley were US$ 17 million** (in 1994 real terms). This translates into an internal rate of return on capital of 13%, which satisfies even the most stringent investment criteria. However, when the two researchers based their calculations on less conservative assumptions, they estimated a 40% rate of return for the Yaqui Valley. About 150,000 hectares of wheat are grown in the Yaqui Valley. Throughout the developing world, where leaf rust affects spring bread wheat on 45–50 million hectares, the rate of return to leaf rust resistance research is probably considerably higher.

## CIMMYT's Resistance Breeding Strategy: The Risk that Paid Off

Breeding for rust resistance presents a special challenge, given that rust pathogens have the troublesome tendency to keep evolving in response to the resistance they encounter in wheat plants. "It used to be that when a new wheat variety was released, no one knew how long its rust resistance would hold up," comments Singh, who is charged with supporting rust resistance breeding at CIMMYT. "Today, thanks to the durable resistance incorporated into modern wheats, farmers can be fairly confident of harvesting a good crop for as long as they plant the variety."

Thirty years ago, resistance breeding centered on finding a major gene that would, by itself, confer effective resistance to a specific rust pathogen. But varieties with "specific" resistance soon succumbed to the targeted pathogen as it evolved into new forms. "It was as if the plant's strong resistant reaction provoked the pathogen into mutating faster," says Singh. "This made breeding for durable rust resistance extremely difficult, like trying to hit a moving target."

In response to this challenge, CIMMYT adopted the resistance breeding strategy that produced the big payoffs revealed by this study. It entailed searching a broad diversity of sources for minor resistance genes that have small, additive effects and incorporating them into CIMMYT's high yielding varieties. Together these accumulated minor genes give wheat "nonspecific" resistance, which allows rust pathogens to infect the crop but slows disease development to the point where yield losses at harvest time are negligible.

When the decision to implement the breeding strategy was taken, there was no assurance that it would work. "The theory underlying the strategy appeared sound, but no one had applied it extensively in a breeding program," explains Sanjaya Rajaram, director of the Wheat Program. Rajaram was instrumental in adopting the strategy and headed the research efforts that culminated in the development of nonspecific resistance. "The decision seems obvious now, but back then it was so risky that not many breeding programs were willing to take it," says Smale.

The strategy has paid off handsomely. CIMMYT-derived varieties possessing nonspecific resistance have not succumbed to major rust epidemics in more than two decades. The **prime beneficiaries of these research dividends are developing country producers,** especially those living in areas where the same wheat varieties are grown over many years or where disease pressure is heavy and the costs of treating disease outbreaks is high.

In the Yaqui Valley itself, wheats with nonspecific resistance have predominated over those with specific resistance since the late 1970s (*see figure*). The only resurgence of specific resistance occurred in 1982–85, when farmers adopted three exceptionally high yielding wheats whose specific resistance broke down within a few years.

## A Major Contribution to Productivity and Sustainability

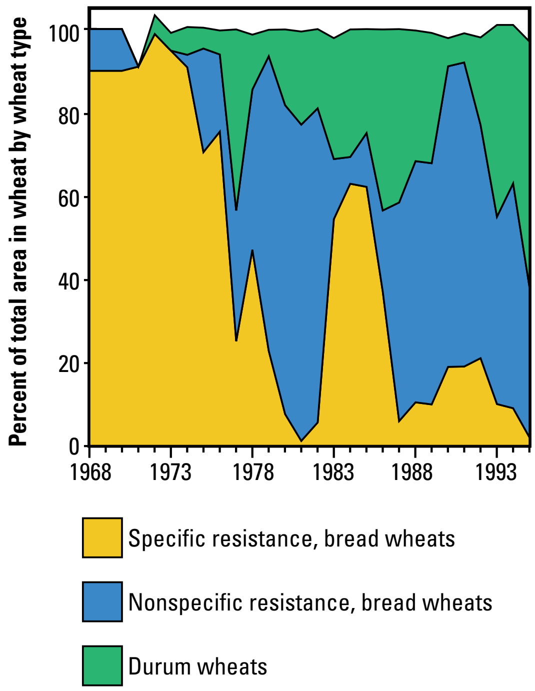
Many mistakenly believe that local wheat varieties offer better protection from diseases and pests than modern wheats. Results of previous CIMMYT studies suggest, however, that improved wheats possess resistance to the three rust diseases that is far superior to that of the old varieties. In fact, **genetic resistance to the three rusts may be the most important contribution of breeding to wheat productivity and sustainability over the past 40 years.**

Recent analyses of trials conducted by Singh and CIMMYT wheat agronomist Ken Sayre in the Yaqui Valley confirm that progress in protecting yield potential through genetic resistance to leaf rust is about three times as great as advances in yield potential itself. Other CIMMYT studies have found that breeding for disease resistance generated a large portion of the global return on the investment in international wheat research over the past few decades. Economics Program survey data indicate that on a global scale the disease resistant, semidwarf wheats developed by CIMMYT and its national research system partners in 1977–90 produced 15.5 million tons of additional grain in 1990 alone, valued at about US$3 billion.

## Other Benefits

Researchers are working to create effective, durable resistance to other diseases through the same strategy of accumulating resistance genes from diverse sources. The benefits from this strategy will continue to accrue into the future as producers deploy these genes through improved seed and avoid crop losses caused by other pathogens.

More Information: **m.smale@cgiar.org**




**Percent wheat area by wheat type and type of leaf rust resistance in the Yaqui Valley from 1968 to 1995.**

# Maize in Ghana: Finding Impact beyond the Figures

Assessing "impact" has become increasingly important as the development community comes under heightened pressure to ensure that resources are used efficiently. But simply appraising whether a technology or project is a "winner" or a "loser" on a tote board basis can be misleading. In their recent study of the Ghana Grains Development Project (GGDP), **CIMMYT economists and their colleagues have gone beyond the ledger to explore less obvious household-level impacts and shed light on the factors that influence adoption of improved technology.** The result is a more detailed, informative picture of how innovations diffuse and people are affected.

"A valid criticism of conventional studies of research impacts is that they focus too much on large-scale surveys and traditional indicators of impact, such as adoption of improved technologies and returns to investment," says CIMMYT economist Michael Morris. "Most studies don't go that one extra step to ask *why* farm households adopt or reject technologies, and when they *do* adopt them, to learn how the welfare of farm households and rural communities is affected."

The impact study of the GGDP, co-authored by Morris, Robert Tripp of the Overseas Development Institute, UK, and A.A. Dankyi of Ghana's Crops Research Institute (CRI), combines traditional quantitative survey methods with qualitative case study techniques (see box, "Drawings Draw Out Farmers' Opinions," p. 40). This approach provides an in-depth evaluation of the GGDP while offering invaluable data on farmers' perspectives about their agricultural needs.

Launched in 1979 with funding from the government of Ghana and the Canadian International Development Agency, the GGDP was charged with developing and diffusing improved technology for maize and grain legumes. CIMMYT and CRI served as the project's primary executing bodies. (See box, "GGDP Achievements at a Glance," next page.)

The impact study had three broad objectives. First, it sought to evaluate the project's effectiveness in developing technologies and transferring them to farmers. Of particular interest were the adoption of modern varieties of maize, fertilizer management recommendations, and plant population management recommendations (specifically, row planting). A second objective was to identify factors explaining adoption and nonadoption at the household level. A third objective was to draw lessons for designing and implementing future projects.

The study also contributed to an effort by the Impact Assessment and Evaluation Group of the Consultative Group on International Agricultural Research (CGIAR) to systematize impact studies across the CGIAR centers, including studies that emphasize nontraditional approaches from rural sociology, anthropology, and psychology.

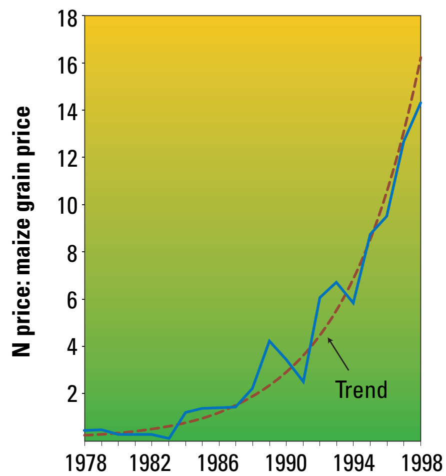
"In one sense the impact study was oriented towards the past, in that we wanted to know what have been the effects of the GGDP," comments Morris. "Then we looked at all the work required to produce a solid national study and recognized this as an opportunity to generate more forward-looking information that breeding programs and policymakers could use."

## The Figures

Judged purely on the basis of adoption levels, the GGDP clearly has been successful. The national figures indicate that the GGDP helped Ghana make considerable strides towards improving productivity of the country's maize sector.

**During 1997, modern varieties (MVs) of maize were grown on 54% of Ghana's maize area**. "This rate is high," state the researchers in their report,* "compared to countries in other parts of the world in which maize is grown mostly by subsistence farmers."

**Farmers applied fertilizer on more than 26% of Ghana's maize area in 1997**. Though considerably lower than MV adoption rates, this level is respectable, given the many constraints to fertilizer use. Adopting fertilizer is a considerably more complex matter than planting seed of a modern variety. Farmer knowledge plays an essential role in unlocking the potential benefits of chemical fertilizer. For this reason, the GGDP expended considerable effort in generating fertilizer recommendations that were readily accessible to farmers. For instance, application rates were stated in terms of condensed milk tins per number of maize plants. Although such efforts were effective in the early years of the project, they could not overcome perhaps the main obstacle to fertilizer adoption in the 1990s: cost. In relation to the maize, fertilizer rose greatly in price since the initiation of the project (*see figure*).




**Nitrogen price-to-maize grain price ratio, Ghana, 1978-98.**

Source: Unpublished Ministry of Agriculture data.

### GGDP Achievements at a Glance

The Ghana Grains Development Project (GGDP) had three distinguishing features. First, it emphasized capacity building for Ghanaian research and extension institutions. Second, it organized an integrated national strategy for technology generation, testing, and diffusion. Finally, it established strong interactions linking station-based research, adaptive farm-level research, and extension. Many achievements contributed to its success. For example:

- Nine maize varieties (eight from CIMMYT lines) were developed and released. Twelve improved cowpea and soybean varieties were released.
- More than 12,000 research and demonstration activities were conducted.
- More than 6,000 persons attended in-service training and crop management research training. Approximately 160 participants took part in eight one-month intensive crop management courses. Forty-three GGDP staff pursued graduate degrees, including 18 PhDs, in Canada, the US, and the UK.
- Nearly 200 publications, including training manuals, farmer handbooks, and socioeconomic studies, were issued.

* M.L. Morris, R. Tripp, and A.A. Dankyi, *Adoption and Impacts of Improved Maize Technology: A Case Study of the Ghana Grains Development Project* (Mexico, D.F.: CIMMYT, 1998).

The story with row planting, the third GGDP-generated technology (designed to improve planting density), is quite different. Implementing row planting requires only a planting rope or sighting poles. The additional cost to the farmer is small and the advantages are large, especially if the farmer is planting MVs. **Just over 55% of Ghana's maize area was planted in rows** during the 1997 major and minor cropping seasons. The strong correlation between row planting and MV adoption indicates that farmers understand the complementarity of the two technologies.

## Did the GGDP Help Rural Households?

What about the project's impact on Ghana's subsistence households? Although Morris and his colleagues caution that assessing such "slippery concepts as well-being" may readily provoke controversy over methods and findings, the importance of the issue justified the endeavor. To ascertain how rural households benefited from GGDP's efforts, the researchers focused on four indicators: agricultural productivity at the farm level, farmer income, nutritional status, and gender equality.

## Drawings Draw Out Farmers' Opinions

When researchers took on the task of organizing a nationwide survey to look at adoption of improved maize varieties, they had little idea what the cards actually held in store. As it turns out, the particular cards developed and used in the Ghana Grains Development Project (GGDP) impact study represented a winning hand for the researchers, paying off in more useful data than originally anticipated.

The challenge in Ghana was to survey large numbers of farmers with varying levels of literacy, diverse languages, and a range of agricultural knowledge and experience. It was critical to have a reliable, unambiguous survey instrument.

Based on preliminary interviews with farmers, the researchers created a list of characteristics of maize varieties that seemed important to different groups of farmers. These characteristics were depicted on flash cards. A maize plant being blown down in a windstorm represented a variety's susceptibility to lodging. Other cards represented an assortment of agronomic and biological characteristics of maize plants, including drought tolerance, nutritional quality, grain quality, and yield.

During the surveys, farmers ranked the importance of the characteristics by placing stones on the cards. Three stones indicated either "very important" or "superior" depending on the question, while one stone represented the least favorable response.

The cards were used in two ways. One application had farmers score the varieties they were currently growing or those with which they had direct experience. Survey enumerators also used the cards to query farmers on how they valued various agronomic and consumer-oriented characteristics of maize. Ghanaian economist A.A. Dankyi and CIMMYT economist Michael Morris will analyze the two sets of responses to determine if what the farmers want is compatible with what they are getting or, as Morris puts it, "Are they really looking for one set of characteristics and getting something else—in which case the breeders may have to revise their strategies."

This interview tool revealed one preference that had changed over the life of the project: grain hardness. Twenty years ago, many Ghanaians didn't like hard, flinty maize because they pounded grain into flour by hand, and hard grain made pounding more laborious. "Now, nearly 100% of the maize in Ghana is ground by machine," remarks Dankyi, "and grain texture is no longer an important consideration. In fact, many people prefer the harder grain because it stores better, being less susceptible to insect damage. This is the kind of information that can help breeders better target their efforts to meet farmers' needs."

The researchers also learned that farmers had a sophisticated appreciation of crop characteristics. "Farmers rarely focused directly on yield as a desirable characteristic in and of itself," Morris comments. "Instead, through the cards they indicated that they focus on the characteristics required to achieve high yields—early maturity, drought resistance, insect and lodging resistance, and so forth. This tells us that the farmers are very knowledgeable about what is required to get good performance in crop varieties. They think in terms of quite sophisticated, disaggregated components, instead of the bottom line. This reinforces something quite important: be careful not to underestimate farmers' traditional knowledge."

Through further analysis of the data, the researchers hope to pinpoint constraints to increased production at the farm level and provide guidance to policymakers and breeders on how to address those problems.

One very positive sign was that **nearly 60% of the farmers surveyed indicated that their maize yields had increased** during the past ten years. Another was that **over half of the farmers surveyed asserted that their incomes had risen** over the same period. They provided evidence for their statements by specifying how the additional income was spent; the most common use was for school fees, followed by the purchase of building materials for the farmer's house.

Nutritional impact was of particular interest because Ghana has promoted quality protein maize (QPM), which possesses unusually high levels of amino acids thought to enhance growth and nutrition. Because maize is a common weaning food in Ghana, it was thought that QPM could especially improve the health of infants and toddlers. The QPM variety Obatanpa ("good weaning mother") was released in 1992 amid considerable efforts to promote its use. **Only 29% of the farmers said they knew about a maize variety that was particularly good for children and infants**; among *that* group, only slightly more than one-third used QPM varieties to prepare weaning foods. Of all the indicators of rural welfare, this was perhaps the least encouraging. The increases in maize productivity and income, however, imply that households have improved overall access to foodstuffs.

Gender effects were examined "not only because women often represent a relatively disadvantaged group . . . but because women tend to make household-level resource allocation decisions that directly influence the welfare of children," report the researchers. **Adoption of both MVs and row planting was found to be higher among men than women**, suggesting that women farmers may face special barriers when it comes to adopting new varieties and technologies. As for fertilizer, cost may have made it equally inaccessible or unprofitable for all farmers, regardless of sex.

While the researchers accept that these results are less conclusive than desirable, they believe the **overall trends show that subsistence farm households are doing better than in the past, partly owing to the GGDP**.

## Factors behind the Figures

Determining farmers' reasons for adopting a technology is rarely a straightforward process, acknowledges Morris. "If you really want to know why 43% of the area in a region is planted to MVs, and not 63% or 23%, you have to take a case study approach to bring out that richness of detail." The approach paid off in the GGDP study as researchers identified three groups of factors—related to the farmer, the technology, and the farming environment—that significantly bear upon adoption.

**One factor strongly influencing adoption was the number of contacts a farmer had with extension agents.** "Extension officers are the major source of information about new technologies, and in many instances they distribute seed or fertilizer as well," Morris explains, a point borne out in the strong correlations between extension contact and adoption of MVs and row planting. The researchers note that in some respects the effects of extension may have been limited: resources for extension work remain scarce in Ghana, and not all farmers have been reached equally.

The effect of a farmer's level of education on adoption is less direct than the effect of extension contact, but education can certainly play a role in the adoption of more complex technologies, such as fertilizer. Not surprisingly the study found that **farmers who adopted one or more of the GGDP technologies had "significantly more formal schooling"** than nonadopters, perhaps because better educated farmers acquire and assimilate new information more readily.

**An unexpected finding was that adoption of GGDP technologies was higher on larger farms**, despite the emphasis given to promoting "scale-neutral" technologies that can be adopted just as easily on small farms. One possible explanation for the difference, the researchers say, could be that even scale-neutral technologies have certain fixed start-up costs, including the time and effort needed to learn about the technology. Such costs are generally less significant for large-scale farmers, who can spread the costs over a more sizeable production enterprise.

An interesting confluence of the latter three factors—extension contact, level of education, and farm size—came to researchers' attention during their analysis of gender differences. "We were careful to ask," says Dankyi, "whether there was something about the technology itself that made it easier for men to adopt, and we concluded that in this case the answer was no. Rather, factors not directly related to the technology seem to affect the uneven rate of adoption by men and women." For example, women had lower levels of education (on average two years less) and farmed smaller plots of land than men. Cultural factors dictating land inheritance and women's access to land almost certainly influenced adoption as well. Perhaps most significant is that men had twice as many contacts with extension agents as women. Although those figures differ by region (women in the Muslim north have far less contact with extension), the implication is that extension needs to be gender neutral or, preferably, that an extra effort should be made to reach women farmers.

## Overall Findings

The impact study has produced considerable data for project contributors, maize breeders, and extension agents. It also has something to say to those interested in technology adoption generally.

"Our overall findings reinforce something we've seen in other studies and that we should communicate better," observes Morris. "Although we are in the business of producing improved technologies and extending them to farmers, we must be realistic and recognize that many factors exceed the control of researchers when it comes to adoption. We must do our best up-front to develop technologies possessing characteristics attractive to our target groups and to focus extension efforts on disadvantaged groups. Even so, we cannot ignore the tremendous influence of cultural factors, which can determine who has access to land, or of political factors, such as subsidies or policy biases towards certain commodities."

More information: **m.morris@cgiar.org**

# Markets and Currencies Grab Headlines in Asian Economic Crisis; Could Food and Grains Be Next?

The financial crisis in Asia abruptly informed the world's leaders and common citizens of the powerful and wide-ranging influence this region exerts on world trade and domestic economies—an influence that extends as well to the wheat and maize fields of developed and developing nations. **Can Asia, home to over two billion people, meet future long-term demand for wheat and maize? And if so, how?** This critical question, with its global implications, is regularly reviewed by CIMMYT economists.

In the wake of the economic turbulence of 1998, Asian grain demand has slumped, grain stocks in exporting countries are exceedingly high, and prices have dived to disconcerting lows. "It would be a grave error, however, if these short-term trends lead the world to a sense of complacency towards the long-term prospects for supplying food to Asia," says Prabhu Pingali, director of CIMMYT's Economics Program.

To ascertain whether and how the vast continent will feed its people, future long-term demand for food and specific cereals must be credibly calculated. "Traditionally, with Asia, economists associated increased demand for cereal crops, in this case wheat and maize, with population growth," says Pingali. "In the 1960s the equation was fairly straightforward for this region: as the population grows, the population-induced need for more food continues to go up."

More recently, stresses Pingali, a new factor entered the equation—increasing incomes. "With increasing incomes, even given the economic crisis of 1998, we see diet diversification taking place. **There are major shifts in the composition of people's diets in the region, which will continue in China and parts of India and resume in force when Southeast Asia gets back on its economic feet."**

Two important trends, spurred by consumers' increased buying power, are emerging. The first is an increase in wheat consumption, tied to the "westernization of the Asian diet." The second is a dramatic rise in maize demand, primarily for animal feed, which is fueled in turn by increased demand for meat and dairy products. (Maize supply and demand are critically important; for details, see box, this page.)

Pingali and Mark Rosegrant of the International Food Policy Research Institute (IFPRI), working with IFPRI's 2020 Global Food Demand/Supply Projections, have sketched out the basic challenges facing the nations of Asia in meeting their growing demand for wheat.

## Can Wheat Supply Meet Rapidly Growing Demand?

By 2020, the demand for wheat in Asia, according to IFPRI projections, will swell to 322 million tons (from 205 tons in 1993), making Asia responsible for 42% of global wheat demand. Behind this tremendous growth lies the aforementioned changes in diet. "The level of per capita wheat consumption is the clearest gauge of the 'westernization' of Asia diets," Pingali explains. "Diet diversification trends are generally observed across Asia, although the extent of substitution out of rice varies by country and region. **Understanding the trajectory of change in food consumption patterns is an essential component of long-term demand projections."**

The trajectory of wheat consumption is up in all nations of the continent, though the rates of increase differ. Rosegrant cites figures showing that **demand is growing fastest in the nations of Southeast Asia, having risen three-fold from 1961 to 1993.** Even with the region's economic woes, wheat demand is expected to double there from the 1993 baseline figure to 2020.

## Growing Demand for Feed Maize Could Harm Poorest of the Poor—Adequate Supply Is the Answer

Although demand for maize, like wheat, has been growing rapidly in Asia, Prahbu Pingali, director of CIMMYT's Economics Program, points out that there are important differences in the trends and demographics pushing the increase, and in future supply options.

In Asia the dramatic rise in demand for meat and other livestock products has fueled higher demand for feed maize, although the turmoil in 1998 slowed that demand. Mark Rosegrant of the International Food Policy Research Institute (IFPRI) projects that China will account for 42% of total world growth in demand for livestock products between 1993 and 2020.

"If to meet that demand, China becomes a major importer," says Pingali, "and we wind up looking at maize imports going from 20 million tons to 80 million tons per year because domestic supply is not forthcoming, then you will definitely see an effect on the world market."

Another side of the maize equation has a much more obvious human dimension. "Traditionally," Pingali explains, "in Asia it's the very poor that consume maize for food. If there's an increased demand for maize for animal feed, you'll see some relative price changes for food maize that could be injurious to the poorest of the poor, whose numbers have grown with the recent economic downturn. Policies promoting improved productivity, particularly aimed at benefiting those living at the subsistence level, could ease the plight of thousands of people, particularly in parts of the Philippines, Vietnam, Indonesia, and India."

Maize differs from wheat on the supply side as well. Maize, unlike wheat, can be productively grown in Southeast Asia. Even more important is the wide yield gap in productive maize areas between technological potential and farmers' actual yields. Greater use of improved technologies and knowledge-intensive management strategies could go a long way towards dramatically increasing supply.

Nevertheless, given the projected needs of Asian nations, Pingali concludes, substantial resources must be dedicated to agronomic and transportation infrastructure and to agricultural research to maximize farmers' yields without depleting the natural resource base.

Wheat demand patterns in **South Asia** differ from those of East and Southeast Asia, Pingali observes. Wheat is the traditional cereal in northern India, Pakistan, Nepal, and northern parts of Bangladesh, and per capita consumption in those areas tends to be relatively stable with respect to income; increased demand there will continue to be driven primarily by population growth. However, he notes, income-induced dietary changes concurrent with the substitution out of rice are now being seen **in southern and eastern India, parts of Bangladesh, and Sri Lanka, where per capita growth in wheat consumption is projected to be a hefty 3.4% annually through 2020.**

In **China**, Pingali sees a **modest increase in wheat demand that is primarily population driven.** Dietary changes are ocurring in China, the economist remarks, but "in northern China we are seeing a drop in per capita wheat consumption, while in southern China we are seeing an increase, so these opposing trends will essentially balance each other out."

How China and India (which together account for 77% of projected Asian wheat demand by 2020) employ their significant production capabilities will undoubtedly influence Asian and global wheat markets.

## What Can Be Done to Meet Wheat Demand?

Increased wheat demand in Asia will have to be met through a combination of increased imports and enhanced domestic production where possible, according to Pingali. Southeast Asia will rely almost exclusively on imports to meet its wheat requirements. **But for China and India and other South Asian countries, a rapid expansion in domestic output growth is absolutely crucial for meeting growing wheat demand. This will not be easily accomplished.**

"The reality," Pingali emphasizes, "is that virtually all future growth in wheat production must come from increased yield per unit of land, because the opportunities for further area expansion are exhausted in Asia."

Aside from limited land area, economic, policy, and environmental factors that constrain production must be addressed. Many farmers on high-potential land, using advanced technologies, have neared a point where additional costs in time or inputs yield only incremental gains, making such investments unattractive. Meanwhile, declining government investments in, for instance, irrigation systems have slowed expansion into potentially productive but unirrigated areas, while leading to a deterioration of existing systems. And, in critical high production regions, such as the Indian Punjab, the Pakistani Punjab, and China's Yangtze River delta, sustainability problems have emerged: the build-up of salinity in the soils has had a deleterious effect on production, which promises to worsen if left unattended.

## Opportunities for Growth in the Wheat Sector

Wheat productivity growth over the next two decades must match growth over the past three decades if the demands of a wheat-hungry world are to be met. Nowhere is the challenge more daunting and a sense of complacency about future wheat supplies more misplaced than in Asia. But it is a challenge that can be met.

Pingali and Sanjaya Rajaram, director of CIMMYT's Wheat Program, have taken an in-depth look at the Asian situation and prepared a detailed assessment on the technological and policy opportunities for increasing wheat productivity growth.

**Investments in research and technology development will have to be made to "shift the yield frontier,"** in other words, to develop wheat varieties that can produce significantly higher yields in productive environments. New plant architecture, hybrids, and novel genetic material incorporated through wide crossing and possibly biotechnology hold great promise on this front (see 1996–97 CIMMYT *Annual Report*, "Wheat Researchers and Farmers Devise New Tactics in the War against Hunger").

Fundamental changes in the use of fertilizers, pesticides, and labor will be required to achieve production increases without proportionate increases in costs to farmers, making adoption of these technologies profitable at the ground level. Integrated pest management and planting on furrow-irrigated raised beds, for instance, can significantly reduce pesticide and herbicide applications and costs.

Resources must be dedicated to improving wheat production in marginal areas already under cultivation, says Pingali, both in terms of yield and sustainability, and especially in China and India. **"Investments in marginal environments are absolutely essential for ensuring urban food supplies, even if countries are integrated into the global economy.** For smaller wheat-producing countries, the prudent strategy would be to invest modestly in such environments."

Whether its eking out additional productivity in a marginal environment or shifting the yield frontier in high productivity areas, Pingali and Rajaram concur that for production growth to increase sufficiently, investments in both agricultural research and farmer education must be forthcoming.

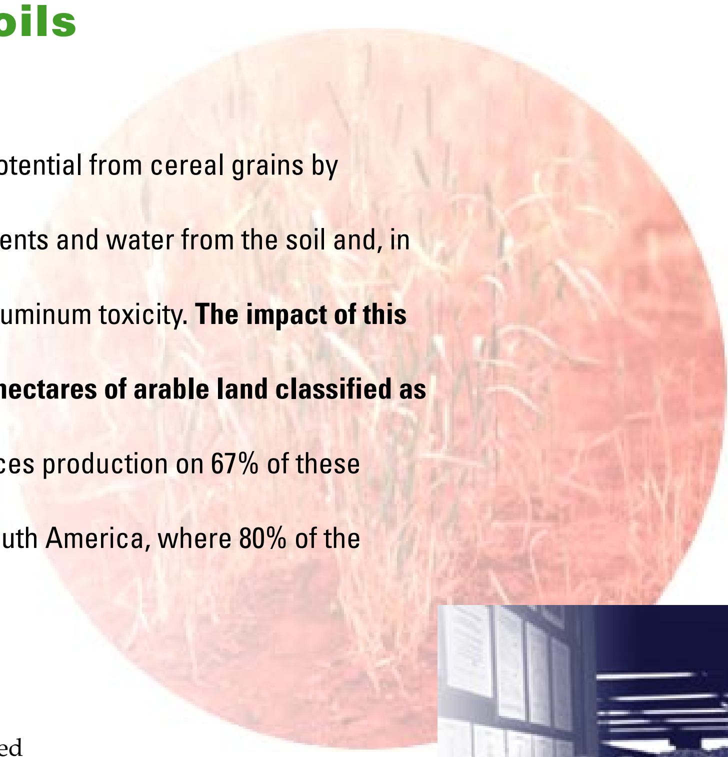
"From the research perspective," says CIMMYT affiliate economist Greg Traxler of Auburn University, **"a major consideration is that knowledge-intensive technologies that lead to greater efficiency are fairly location specific, and so the cost of developing such technologies relative to likely impacts may be high."**

Pingali adds that policymakers and researchers must also realize that such knowledge-intensive technologies come at a significant cost in the time required of farmers to learn, manage, and make decisions related to the system.

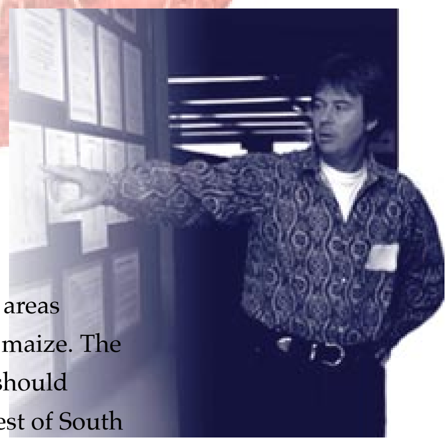
More Information: **p.pingali@cgiar.org**

# Research Update/Outlook

# CIMMYT on Course with Biotech Response to Aluminum Toxicity in Soils



Acid soils rob vegetative growth and yield potential from cereal grains by reducing the plant's capacity to absorb nutrients and water from the soil and, in many instances, promoting problems with aluminum toxicity. **The impact of this production factor is global, with 1.7 billion hectares of arable land classified as acidic**. Aluminum toxicity negatively influences production on 67% of these soils. The problem is particularly acute in South America, where 80% of the agricultural land is acidic.



CIMMYT is engaged in two projects* directed towards maize and wheat that address this problem at the genetic and molecular levels and provide the foundation for future advances. The overall strategy, which encompasses both projects, says molecular geneticist Jean-Marcel Ribaut, is directed at understanding the genetics of aluminum tolerance (the number and location of genes, and the physiological basis of tolerance) with the aim of developing molecular markers linked to these genes. The markers could then be used to transfer aluminum-tolerance genes to other maize and wheat germplasm.

## Work on Maize

The maize project, developed by CIMMYT's Maize Program and Applied Biotechnology Center, and supported by the Colombian Corporation of Agricultural Research (CORPOICA), will develop maize cultivars and hybrids, and accompanying technologies and cropping systems, for the acid savannas of Colombia. To date a linkage map has been produced based on $F_2$ genetic data. The next breeding cycle, conducted by CIMMYT breeders in Colombia, will provide phenotypic data that doctoral candidate Alejandro A. Navas and the CIMMYT team will use to locate genomic areas affecting acid tolerance in maize. The benefits from this project should eventually extend to the rest of South America and the world.

## Work on Wheat

On the wheat front, researchers seek first to identify the genes for aluminum tolerance in rye—a related species with a simpler genetic system—and then to transfer those genes to wheat. The project has already collected the phenotypic and genetic data that graduate student Arne Hede is using to identify the genomic regions of interest. At least one major gene was identified in July 1998. Markers closely linked to the gene will be used to follow the transfer of the aluminum tolerance allele into the wheat genome. The same marker (already mapped on the wheat genome to chromosome 4) may well be used to screen wheat accessions in the future. Hede's research has been supported by the Danish International Development Agency and CIMMYT (through the wheat germplasm bank and the Applied Biotechnology Center).

* Molecular Studies for Linkage Analysis and Determination of Quantitative Trait Loci for Acid Soil Tolerance in Maize; Aluminum Tolerance in Rye (*Secale cereale* L.): Dissecting the Genetic Control.

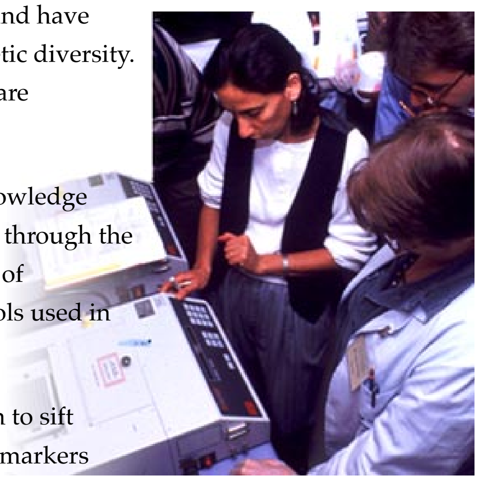
More Information: **j.ribaut@cgiar.org**

# Fingerprinting Historic Wheats

Have modern breeders increased or decreased genetic diversity in wheat? **CIMMYT scientists need an answer to this question to determine whether their efforts are making wheats more genetically uniform**, and hence more vulnerable to disease, insect threats, and adverse environmental conditions, or if their work is maintaining or even increasing genetic diversity in wheat.

CIMMYT molecular geneticist Mireille Khairallah and Isabel Almanza, a Colombian graduate student studying at the Colegio de Postgraduados, Montecillo, Mexico, are examining 15 "historic" CIMMYT wheat varieties (widely grown varieties released in northwestern Mexico between the late 1960s and the late 1980s). Using new molecular markers (AFLPs and microsatellites), they are looking at a range of variables to determine the molecular distance between the varieties, which is an indicator of genetic diversity.

Previous CIMMYT studies have addressed the diversity issue by looking at traits such as rust resistance, as well as coefficients of parentage, and have concluded that the Center is doing well in maintaining genetic diversity. "We have taken the varieties used in the earlier studies and are examining them at the molecular level," says Khairallah.



An important offshoot of this work will be increased knowledge about the relationship between genetic distance determined through the use of biotechnology and statistically calculated coefficients of parentage. In addition, the development of the biometric tools used in this study will be helpful in future research on diversity.

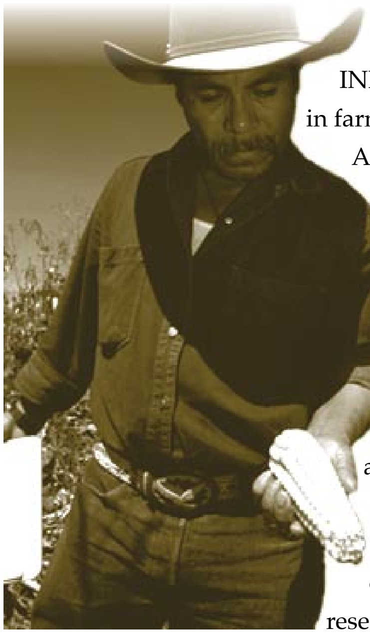
During the upcoming year Khairallah and Almanza plan to sift through their findings and reduce the number of molecular markers needed for precisely determining genetic distance, thus reducing the work and time required to compare varieties with accuracy. This would represent a modest but necessary step towards the achievement of a grander goal: the fingerprinting and characterization of thousands of accessions of wheat now held in CIMMYT's gene bank. Such work, in turn, could greatly expedite the future use of gene bank materials by wheat breeders and other scientists (see "Opening Gene Bank Doors a Little Wider," p. 24).

More Information: **m.khairallah@cgiar.org**

# *In Situ* Conservation of Mexican Maize Landraces: Capitalizing on Farmer-Breeders' Knowledge

As part of a joint effort begun in 1997 to help smallholders in the Central Valleys of Oaxaca, Mexico, preserve selected maize landraces, CIMMYT and the Mexican National Institute for Forestry, Agriculture, and Livestock Research (INIFAP) will soon **return improved versions of landrace seed to farmers who participated in the selection and improvement process**. The work is funded by the governments of Mexico and Japan and the International Development Research Centre, Canada.

Suketoshi Taba, head of maize genetic resources at CIMMYT, and INIFAP breeder Flavio Aragón Cuevas collected more than 150 samples of the local landrace Bolita from farmers throughout the region. Assisted by INIFAP agronomist Humberto Castro García, they sowed trials including all samples, plus selected Bolita collections from CIMMYT and INIFAP's germplasm banks, in farmers' fields at 15 villages. At harvest, they organized field days at six sites where more than 500 local farmers and others from the region scored trial entries for grain quality, forage production, and other key traits. Those data were combined with yield data taken by the researchers to place trial entries into five groups, representing the diversity of plant and ear types.



Outstanding samples were then selected and improved for yield, grain and ear quality, and early maturity (a characteristic highly valued by local farmers). Seed of the best is being increased for distribution to participating farmers, and all samples, original and improved, will be conserved in the CIMMYT and INIFAP banks. A socioeconomic follow-up study will assess farmers' use of the improved landrace seed. "Farmers receive an improved product, but the grain and plant type and maturity traits they prefer are still there," Taba says.

Selection resulted in a subset of Bolita (20% of the seed collections) that fairly represents its racial diversity and can be further improved by INIFAP breeders. "Because of breeders' demand for higher yielding landraces, such as Tuxpeño, landraces grown by poor farmers under marginal conditions for specialty uses have been under-sampled in efforts to collect and conserve maize genetic resources," Taba explains. "Our approach integrates *in situ* and *ex situ* conservation of extant landrace diversity." Farmers participate in documenting seed samples at the time of collection, in evaluating them, and choosing desired populations. They help breeders select and recombine progeny as part of the improvement process. Researchers in turn obtain knowledge about farmers' use of landraces and, using farmer criteria and participation, arrive at breeding strategies that are more attuned to farmers' needs.

More Information: **s.taba@cgiar.org**

# Study to Clarify the Role of Genetic Diversity in Production Systems

Take survey information at the household and aggregate level from the world's largest wheat producer, combine it with data and expertise from a global leader in researching genetic diversity in wheat, and you have the basic ingredients for **a heavyweight study on the relationship between genetic diversity and wheat productivity**—a critical issue for wheat breeders and policymakers.

With funding from Australia and support from Australian and Chinese institutions,* CIMMYT in late 1997 began a two-year study that will have far-reaching applications. Using various measurement techniques, the study will assess levels of genetic diversity in China and Australia and examine the complex interaction of diversity with crop productivity, stability, household preferences for growing different kinds of wheat varieties, and policy.

## Work in Contrasting Settings

China and Australia were chosen for comparison because their wheat production systems are quite different in terms of commercialization, policies affecting crop breeding and research, and the incentives leading households to grow different types of wheat varieties.

Investigating farm-level selection of wheat varieties and resulting diversity outcomes is an important element of the China research. Erika Meng, a Rockefeller Fellow assigned to CIMMYT, worked with the Chinese Academy of Agricultural Sciences/Center for Chinese Agricultural Policy (CAAS/CCAP) to conduct a household survey in June 1998. The survey will increase our understanding of the wheat production and consumption characteristics that influence the household's decision about which variety to grow. Data will also be used to measure wheat diversity at the farm level. Furthermore, results of the household study will help identify incentives for farmers to continue growing certain kinds of varieties rather than others and will also guide future wheat breeding efforts. Very few, if any, traditional varieties are grown in the survey areas, so the study will focus mostly on farmers' choice of improved wheat varieties.

Another aim of the China research is to examine aggregate changes in genetic diversity over time and compare the effects of different policies in the major wheat-producing provinces on genetic diversity. This component of the study will break new ground, as the data required to examine wheat genetic diversity have been unavailable in China until now. CIMMYT is collaborating closely with CAAS/CCAP to amass this extensive database. Once completed, this resource, containing information on wheat pedigrees, area planted to cultivars over time, yield performance, and a range of other plant and agronomic characteristics, will provide important baseline data in a number of contexts.

The Australian component of the study focuses on how changes in research policies, research priorities, and wheat marketing have affected genetic diversity and the supply of varieties. Most data have already been collected and are being updated.

## A New Research Framework

To make full use of the data from the diverse settings provided by China and Australia, researchers are developing a theoretical and methodological framework to address the many questions about the relationships between genetic diversity, policy, and farmers' choice of varieties. A major product of the study will be a sophisticated research construct that incorporates genetic diversity issues into the economic analysis of production systems, an endeavor complicated by the multitude of definitions of "genetic diversity" and of methods used to measure it. The development of the framework will be a milestone in efforts to understand the role that genetic diversity plays and will greatly contribute to CIMMYT's broader project on Global Genetic Resource Conservation and Management.

More Information:
**e.meng@cgiar.org**

* **The Australian Centre for International Agricultural Research provided funds; support is provided by the University of Sydney, the New South Wales Department of Agriculture, and the Chinese Academy of Agricultural Sciences/Center for Chinese Agricultural Policy.**

## Enhancing Research Management in
# Latin America

March 1998 saw a new project launched by CIMMYT's Economics Program, targeted at identifying the major variables that affect the productivity of maize and wheat research systems in Latin America. With that information in hand, **the project can examine and recommend ways to improve the efficiency of the national institutions responsible for research on these critical commodities**. Funded by the Inter-American Development Bank (IDB), the three-year project will draw on expertise and data from collaborating institutions throughout Latin America.* During the upcoming year, project members will develop and verify methodologies and gather data on maize and wheat research institutions throughout the region.

### Project Components and Methodology

The project has five components, which should produce a clear picture of where opportunities for increasing efficiency lie: 1) institutional analysis; 2) analysis of flows of "pre-technologies" (for instance, improved lines used by national research systems but not yet publicly released); 3) analysis of flows of released genetic technologies; 4) analysis of flows of crop management technologies; and 5) analysis of the variables that influence production of genetic technologies (for instance, new varieties).

Although CIMMYT has studied flows of varieties and pre-technology in some Latin American countries, work on institutional analysis, crop management technologies, and the cost of producing the technologies is new, according to CIMMYT economist and project coordinator Javier Ekboir.

At the institutional level, the research team will look at incentives and disincentives within institutes, staffing levels, the stability of budgets, and other factors that bear on research efficiency. This will be the first effort conducted in Latin America on such a broad scale.

Meanwhile, to look at the flows of crop management technologies, project members will develop and test two new methodologies, says Ekboir. One, to be used in Central America, will identify several technologies that farmers use and attempt to trace them to their origins. The second, to be used in South America, will monitor a technology that scientists believe has the potential to spread widely, observing factors that constrain or enhance its diffusion.

### Novel Insights into the Future Course of Research Management

Getting at the factors that influence the generation of new varieties, the project's fifth component, should offer some novel insights, Ekboir believes. Using the data collected at the institutional level, the research team will identify economies and diseconomies of size and scope. They will also investigate how germplasm spillovers (use of varieties or breeding material outside the areas for which they were developed) and institutional factors affect research productivity. The goal is to answer a critical question for research management: does the cost of producing a variety rise or fall with the number of researchers and/or number of programs at an institution?

All of this must be viewed in an international context, Ekboir adds. For instance, in the past, technology flowed from the larger national agricultural research systems (NARSs) to the smaller ones. The reasons for this pattern are still not clear, raising a key point of inquiry for the study team. Would expanding the capacity of smaller NARSs lead to a bi-directional flow of knowledge and germplasm and increase opportunities for the larger NARSs? A host of related issues emerge from this question. Should a smaller NARS invest in a larger NARS' research efforts, rather than its own? Is a larger system more efficient? Are collaborative networks, formed by smaller programs, more productive than a single large program? How will intellectual property rights and technical change affect research opportunities for larger and smaller NARSs? In responding to these questions, the study could have a direct bearing on the future course of agricultural research management in Latin America.

More Information: **j.ekboir@cgiar.org**

* **Including Argentina's INTA, Bolivia's CIAT, Brazil's EMBRAPA, Central America's Regional Maize Program, Mexico's INIFAP, Paraguay's DIA/MAG, and IDB.**

# Financial Highlights, 1997/98

**Other sections of this report attest to the many research endeavors that are transforming farming communities throughout the world. In these Financial Highlights, we draw readers' attention to the financial trends and funding organizations that enable our research to make a difference.**

## Funding Trends at a Glance

Funding for 1997 was US$ 30.607 million, consisting of US$ 28.825 million from donors and US$ 1.782 million from other sources. Expenditures were US$ 30.978 million. Sources of income from grants are summarized in the box, p. 55.

Figures 1–4 provide a quick overview of funding levels and trends. The ten agencies that provided most of the Center's funding in 1997 are shown in Figure 1. Figure 2 shows how funds were allocated within CIMMYT among the five CGIAR research activities. The continuing decline in unrestricted contributions and the rise in targeted contributions (i.e., special project and restricted funding) over the past several years is apparent from Figure 3. The growing importance of targeted funding throughout the Center can be seen in Figure 4, which shows the distribution of core special project, core restricted, and core unrestricted funding by research program and administrative activity for 1997. Although some CIMMYT research programs, most notably the Applied Biotechnology Center, receive considerable support from targeted funding, the difficulty in attracting sufficient funding for the Center's core research activities remains a cause for concern. As expected, the Center's research support, external relations, and administrative functions have continued to rely almost entirely on unrestricted funding.

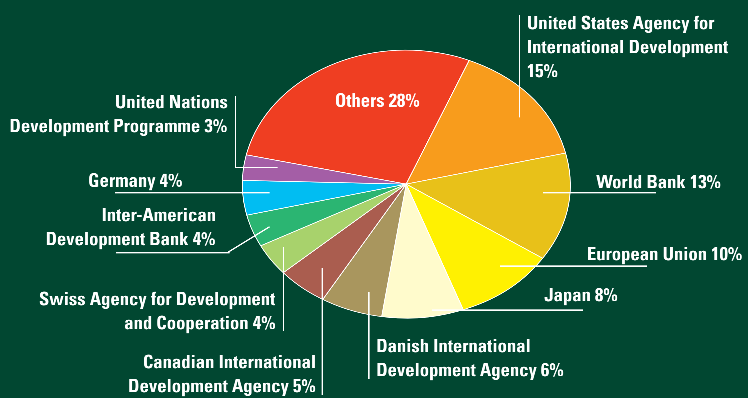



Figure 1. Top ten donors to CIMMYT, 1997.

Figure 2. Allocation of CIMMYT research funding by CGIAR activity, 1997.

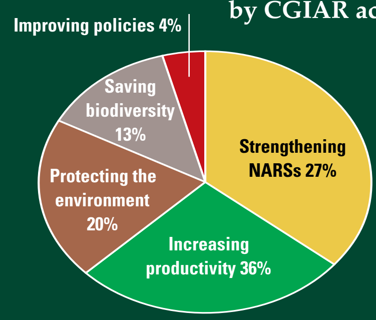
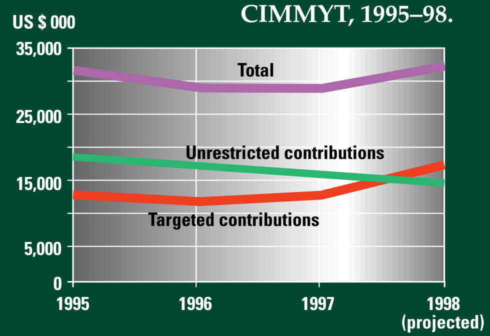



Figure 3. Trends in grants to CIMMYT, 1995–98.



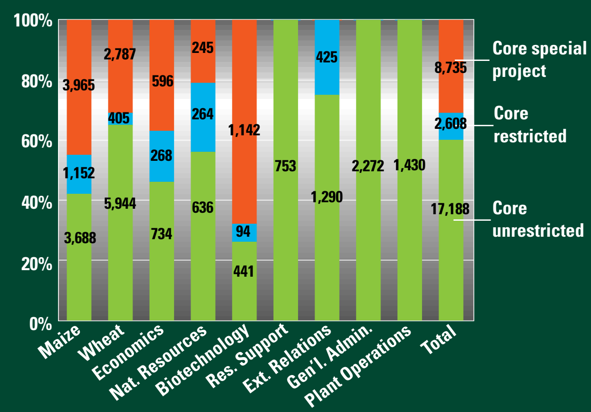




Figure 4. CIMMYT expenditures by type of funding, 1997.

# Finances in 1997-98

Finances in 1997-98

The Center ended 1997 with an operational deficit of US$ 371,000, which essentially corresponded to the cost of the External Program and Management Review and related activities conducted throughout the year. These funds represented 1.22% of CIMMYT's total operating expenses and were charged against the operating reserve, leaving a balance of US$ 8,000,000 as a much-needed reserve for future funding uncertainties. The Board of Trustees had approved a deficit of US$ 300,000 for 1997.

Significant changes in donors' contributions occurred in 1997. Exchange rate losses on contributions from several countries (Japan, Denmark, Germany, and Canada) occasioned major deviations from the projected budget. Financial conditions in France dictated an unforeseen reduction in donations, and unrestricted contributions initially expected from Belgium and Italy were not received; these circumstances resulted in a decrease in the matching contribution from the World Bank.

Cash flow difficulties reached a critical state from September to November, as several major contributions did not arrive until the end of 1997 or beginning of 1998. Contributions from the European Union (for 1996 and 1997) and the Inter-American Development Bank were outstanding until 1998.

Despite these vicissitudes, three positive factors helped to ease the gap in funding by the end of 1997. The Government of Portugal made a new contribution of US$ 500,000, some of which was applied to the 1997 budget;* higher revenues were received from Center income; and a Center-wide reduction in expenditure was made.

Expenditures related to core special projects were below the level initially projected, generally because projects were initiated later than expected or because project funds had been under-utilized in the course of the year. After the year-end closing of the books on these projects, a sum of US$ 2.1 million was carried forward to 1998. At the end of 1997, CIMMYT's working capital was 94 days, slightly higher than the 90 days recommended by the CGIAR. CIMMYT's total capital expenditures (replacement plus additions) were below the normal amount set on depreciation (US$ 1.4 million). Therefore it was unnecessary to replenish the capital fund from working capital and, on the contrary, the capital fund had grown by US$ 347,000 by the end of the year.

The fiscal caution exercised during 1997 proved critical in 1998, when the funding situation became even more volatile. A combination of circumstances (the late arrival of contributions, exchange rate effects, and some erosion of donor funds as donors sought to address shortfalls in their own budgets) have contributed to serious cash flow problems and a reduction on investments, which have affected total Center income.

Despite these challenging circumstances, CIMMYT has managed to carry on with an ambitious research agenda. During 1997, 28 new special projects were launched, representing more than US$ 15 million over the next few years. In 1997 and 1998, to facilitate collaborative research in two areas of the world where a considerable impact can be made, CIMMYT opened offices in Beijing and Kazakstan. Finally, we remain committed to seeking the additional funding that will ensure that important areas of research are not neglected.

---

* Subsequent information received in March 1998 from Portugal and the CGIAR indicated that the Portuguese contribution was for 1998, not 1997. This affected our financial plans for 1998.

## CIMMYT Research Agenda Financing Summary

**For the period from January 1 to December 31, 1997**
(US $ 000s)

| Donor | Unrestricted contributions | Targeted contributions | Total |
|---|---|---|---|
| Asian Development Bank | | 113 | 113 |
| Australia, Government of | 696 | 117 | 813 |
| Austria, Government of | 150 | 7 | 157 |
| Bangladesh Rice Research Institute | | 59 | 59 |
| Belgium, Government of | | 305 | 305 |
| Canadian International Development Agency | 782 | 776 | 1,558 |
| Centre de Coopération Internationale en Recherche Agronomique Pour le Développement | | 3 | 3 |
| Centro Internacional de Agricultura Tropical | | 58 | 58 |
| China, People's Republic of | 80 | 0 | 80 |
| Colciencias-Colombia | | 153 | 153 |
| Colombia, Government of | | 155 | 155 |
| Cornell University | | 76 | 76 |
| Danish International Development Agency | 1,727 | 80 | 1,807 |
| Department for International Development, UK | | 892 | 892 |
| Empresa Brasileira de Pesquisa Agropecuaria, Brasil | 100 | 0 | 100 |
| European Union | 250 | 2,664 | 2,914 |
| Ford Foundation | 400 | 0 | 400 |
| France, Government of | | 425 | 425 |
| Germany, Government of | 455 | 575 | 1,030 |
| Grains Research and Development Corporation, Australia | | 173 | 173 |
| India, Government of | 75 | 0 | 75 |
| Inter-American Development Bank | | 1,140 | 1,140 |
| International Centre for Research in Agroforestry | | 50 | 50 |
| International Development Research Centre | | 58 | 58 |
| International Food Policy Research Institute | | 81 | 81 |
| International Fund for Agricultural Development | | 240 | 240 |
| International Plant Genetic Resources Institute | | 52 | 52 |
| Islamic Republic of Iran, Government of | | 330 | 330 |
| Italy, Government of | | 83 | 83 |
| Japan, Government of | 2,270 | 47 | 2,317 |
| Korea, Republic of | 50 | 24 | 74 |
| Leverhulme Trust ,The | | 44 | 44 |
| Mexico, Goverment of | 120 | 192 | 312 |
| Miscellaneous research grants | | 1 | 1 |
| Monsanto Company | | 75 | 75 |
| National Institute of Agriculture Research, Uruguay | | 110 | 110 |
| Netherlands, Government of | | 414 | 414 |
| Norwegian Ministry of Foreign Affairs | 117 | 19 | 136 |
| OPEC Fund for International Development | | 43 | 43 |
| Pakistan, Government of | 100 | 0 | 100 |
| Philippines, Government of | 25 | 0 | 25 |
| Portugal, Government of | 250 | 0 | 250 |
| Republic of South Africa | | 28 | 28 |
| Rockefeller Foundation | | 366 | 366 |
| Spain, Government of | 20 | 80 | 100 |
| Stanford University | | 15 | 15 |
| Swedish International Development Cooperation Agency | | 96 | 96 |
| Swiss Agency for Development and Cooperation | 139 | 1,052 | 1,191 |
| Thailand, Government of | 100 | 0 | 100 |
| The Nippon Foundation | | 218 | 218 |
| Tropical Agriculture Research Center, Japan | | 25 | 25 |
| United Nations Development Programme | | 997 | 997 |
| United Nations Development Programme (Africa) | | 18 | 18 |
| United States Agency for International Development | 4,350 | 78 | 4,428 |
| United States Department of Agriculture | | 211 | 211 |
| Wisconsin University | | 51 | 51 |
| World Bank | 3,700 | | 3,700 |
| **Total** | **15,956** | **12,869** | **28,825** |

# Trustees and Principal Staff

(as of September 1998)

## Trustees



1 *Ex officio* position.

## Principal Staff

### Office of the Director General

**Timothy G. Reeves**, Australia, Director General[6]
**Claudio Cafati**, Chile, Deputy Director General of Administration and Finance
**Lucy Gilchrist S.**, Chile, Senior Scientist, Head, Seed Health Unit
**Zhong-Hu He**, China, China Liaison Scientist (based in Beijing)[1]
**Patricia López–M.**, Mexico, Executive Assistant to the Director General
**Gregorio Martínez V.**, Mexico, Government and Public Affairs Officer
**Peter J. Ninnes**, Australia, Senior Executive Officer, Research Management[1]

**Consultant/Research Affiliate**
**Norman E. Borlaug**, USA

### External Relations Program

**Tiffin D. Harris**, USA, Director
**Anne Starks Acosta**, USA, Donor Relations Officer II
**Leslie Rose**, USA, Public Awareness Officer II[2]

**Publications and Communications**
**Kelly A. Cassaday**, USA, Senior Publications Manager
**G. Michael Listman**, USA, Writer/Editor II
**Alma L. McNab**, Honduras, Senior Writer/Editor and Translations Coordinator
**Miguel Mellado E.**, Mexico, Publications Production
**David A. Poland**, USA, Writer/Editor II[3]

**Information Technology Unit**
**Edith Hesse**, Austria, Information Technology Manager
**Jesús Vargas G.**, Mexico, Systems and Operations
**Guillermo Ibarra B.**, Mexico, PC Support and Integration[4]
**Rafael Herrera M.**, Mexico, Software Development
**Carlos López**, Mexico, Project Leader, Software Development
**Héctor Sánchez V.**, Mexico, Project Leader, Software Development

**Library**
**Corinne de Gracia**, Mexico, Head
**Fernando García P.**, Mexico, Electronic Information Specialist
**John Woolston**, Canada, Visiting Scientist

**Consultant/Research Affiliate**
**Jonathan Woolley**, UK[4]

### Maize Program

**Shivaji Pandey**, India, Director[3,6]
**Richard Wedderburn**, Barbados, Associate Director[6]
**Danilo Baldos**, Philippines, Scientist, Agronomist/Coordinator, Crop Management Training (based in Thailand)[4]
**Marianne Bänziger**, Switzerland, Scientist, Physiologist (based in Zimbabwe)[6]
**David Beck**, USA, Senior Scientist, Leader, Highland Maize
**David Bergvinson**, Canada, Scientist, Entomologist[6]
**Javier Betrán**, Spain, Scientist, Breeder[2]
**Jorge Bolaños**, Nicaragua, Senior Scientist, Agronomist (based in Guatemala)[6]
**Hugo Córdova**, El Salvador, Principal Scientist, Breeder/Leader of Tropical Maize[6]
**Carlos de León G.**, Mexico, Principal Scientist, Pathologist/Breeder (based in Colombia)
**Alpha O. Diallo**, Guinea, Senior Scientist, Breeder (based in Kenya)
**Gregory Edmeades**, New Zealand, Principal Scientist, Crop Physiologist
**Dennis Friesen**, Canada, Senior Scientist, Agronomist (based in Kenya)[3]
**Daniel Jeffers**, USA, Senior Scientist, Pathologist
**David Jewell**, Australia, Senior Scientist, Breeder (based in Zimbabwe)[6]
**James Lothrop**, USA, Senior Scientist, Breeder (based in Thailand)[2]
**Luis Narro**, Peru, Scientist, Breeder (based in Colombia)
**Kevin V. Pixley**, USA, Senior Scientist, Breeder (based in Zimbabwe)
**Joel K. Ransom**, USA, Senior Scientist, Agronomist (based in Kenya)
**Ganesan Srinivasan**, India, Senior Scientist, Leader, Subtropical Maize, and Head, International Testing Unit
**Suketoshi Taba**, Japan, Senior Scientist, Head, Maize Germplasm Bank
**S. Twumasi-Afriyie**, Ghana, Scientist, Breeder (based in Ethiopia)[2]
**Surinder K. Vasal**, India, Distinguished Scientist, Breeder/Liaison Officer (based in Thailand)[6]
**Stephen Waddington**, UK, Senior Scientist, Agronomist/NRG Associate (based in Zimbabwe)
**Martha Willcox**, USA, Scientist, Breeder/Applications of Biotechnology[2]
**Batson Zambezi**, Malawi, Scientist, Breeder (based in Zimbabwe)

**Associate Scientists**
**Miguel Barandiarán**, Peru, Breeder
**Benoit Clerget**, Switzerland (based in Colombia)[4]
**Salvador Castellanos**, Guatemala, Breeder
**Anne Elings**, the Netherlands, Physiologist[2]
**Fred Kanampiu**, Kenya, Breeder (based in Kenya)[1]
**Harish Kumar**, India, Entomologist[2]
**Byung-Ryeol Sung**, South Korea, Breeder[2]
**Benti Tolessa**, Ethiopia, Breeder[3]

**Pre- and Postdoctoral Fellows**
**Anthony Esilaba**, Kenya (based in Ethiopia)[4]
**Jerome Fournier**, Switzerland (based in Guatemala)[4]
**Jan Hirabayashi**, USA, Entomologist[2]
**Julien de Meyer**, Switzerland[3]
**Stephen Mugo**, Kenya, Physiologist[3]
**Sai Kumar Ramanujam**, India, Breeder[2]
**Bindiganavile Vivek**, India, Breeder[1]

1 Appointed in 1997.
2 Left in 1997.
3 Appointed in 1998.
4 Left in 1998.
5 Visited for a minimum of 2–3 months.
6 Project Coordinator.

**Consultants/Research Affiliates**
**Gonzalo Granados R.**, Mexico, Training Consultant
**Felix San Vicente**, Venezuela[2]

## Wheat Program

**Sanjaya Rajaram**, India, Director
**H. Jesse Dubin**, USA, Associate Director
**Osman S. Abdalla**, Sudan, Senior Scientist, Bread Wheat Breeder (based in Syria)
**Arnoldo Amaya**, Mexico, Administrative Manager
**Hans-Joachim Braun**, Germany, Senior Scientist, Breeder (based in Turkey)[6]
**Etienne Duveiller**, Belgium, Senior Scientist, Pathologist (based in Nepal)
**Paul Fox**, Australia, Senior Scientist, Manager, International Nurseries
**Guillermo Fuentes D.**, Mexico, Scientist, Pathologist (Bunts/Smuts)
**Lucy Gilchrist S.**, Chile, Senior Scientist, Pathologist (Fusarium/Septoria)
**Maarten van Ginkel**, the Netherlands, Senior Scientist, Head, Bread Wheat Breeding[6]
**Monique Henry**, France, Scientist, Virologist
**Muratbek Karabayev**, Kazakstan, International Liaison Scientist (based in Kazakstan)[3]
**Gunther Manske**, Germany, Scientist, Physiologist[2]
**Mohamed Mergoum**, Morocco, Senior Scientist, Head, Triticale Breeding
**A. Mujeeb-Kazi**, USA, Principal Scientist, Head, Wide Crosses
**Man Mohan Kohli**, India, Principal Scientist, Breeder (based in Uruguay)
**Guillermo Ortiz Ferrara**, Mexico, Principal Scientist, Breeder (based in Nepal)
**Ivan Ortiz-Monasterio**, Mexico, Scientist, Agronomist
**Alexei Morgounov**, Russia, Scientist, Breeder (based in Turkey)
**M. Miloudi Nachit**, Germany, Senior Scientist, Durum Wheat Breeder (based in Syria)
**Thomas S. Payne**, USA, Scientist, Breeder (based in Ethiopia)
**Roberto J. Peña**, Mexico, Senior Scientist, Head, Industrial Quality
**Wolfgang H. Pfeiffer**, Germany, Senior Scientist, Head, Durum Wheat Breeding[6]
**Matthew P. Reynolds**, UK, Scientist, Head, Physiology[6]
**Eugene E. Saari**, USA, Principal Scientist, Pathologist/Breeder (based in Nepal)[2]
**Kenneth D. Sayre**, USA, Principal Scientist, Head, Crop Management
**Ravi P. Singh**, India, Principal Scientist, Geneticist/Pathologist (Rust)[6]
**Bent Skovmand**, Denmark, Senior Scientist, Head, Wheat Germplasm Bank, and Genetic Resources
**Douglas G. Tanner**, Canada, Senior Scientist, Agronomist (based in Ethiopia)
**Richard Trethowan**, Australia, Scientist, Bread Wheat Breeder[1]
**George Varughese**, India, Principal Scientist, Leader, Maize/Wheat Network (based in Zimbabwe)
**Reynaldo L. Villareal**, Philippines, Senior Scientist, Head, Germplasm Improvement Training[6]
**Patrick C. Wall**, Ireland, Principal Scientist, Agronomist/NRG Associate (based in Bolivia)

**Associate Scientists**
**Janny van Beem**, Colombia, Physiologist
**Belgin Çukadar**, Turkey, Breeder
**Arne Hede**, Denmark, Geneticist

**Adjunct Scientists**
**Hugo Vivar**, Ecuador, Senior Scientist, Head, ICARDA/CIMMYT Barley Program
**Masanori Inagaki**, Japan, Associate Scientist, Cytogeneticist[4]

**Postdoctoral Fellow**
**Julie Nicol**, Australia, Nematologist[3]

**Graduate Students**
**Ligia Ayala**, Ecuador
**Subhash Ch. Tripathi**, India

**Consultants/Research Affiliates**
**Maximino Alcalá**, Mexico[1]
**Julio Huerta**, Mexico
**Ernesto Samayoa**, Mexico

## Economics Program

**Prabhu Pingali**, India, Director
**Mauricio Bellon**, Mexico, Scientist, Human Ecologist[1]
**Javier Ekboir**, Argentina, Scientist, Economist[3]
**Paul W. Heisey**, USA, Senior Scientist, Economist[6]
**Mulugetta Mekuria**, Ethiopia, Scientist, Economist (based in Zimbabwe)
**Erika Meng, USA**, Economist and Rockefeller Foundation Visiting Research Fellow[1]
**Michael Morris**, USA, Senior Scientist, Economist[6]
**Wilfred M. Mwangi**, Kenya, Principal Scientist, Economist (based in Ethiopia)
**Ma. Luisa Rodríguez**, Mexico, Program Administrator
**Gustavo E. Sain**, Argentina, Senior Scientist, Economist (based in Costa Rica)
**Melinda Smale**, USA, Senior Scientist, Economist

**Adjunct Associate Scientists**
**Damien Jourdain**, France, Economist[1]
**Hugo Verkuijl**, the Netherlands, Economist (based in Ethiopia)

**Postdoctoral Fellow**
**Monika Zurek**, Germany, Economist (based in Costa Rica)[1]

**Research Associates**
**Alfonso Aguirre**, Mexico, Human Ecologist[1]
**Dagoberto Flores**, Mexico, Field Researcher
**Roberta Gerpacio**, Philippines, Economist (based in the Philippines)[3]
**Miguel Ignacio Gómez**, Colombia, Economist
**Maximina Lantican**, Philippines, Economist
**Naresh Pradhan**, Nepal, Economist[2]
**Jean Risopoulos**, Belgium, Economist
**Manisha Shah**, USA, Economist

**Consultants/Research Affiliates**
**John Brennan**, Australia, Economist
**David Cleveland**, USA, Economist
**Cheryl Doss**, USA, Economist
**David Godden**, Australia, Economist
**Douglas Gollin**, USA, Economist
**Jikun Huang**, China, Economist
**Janet Lauderdale**, USA, Nutritionist
**Miguel Angel López**, Honduras, Economist
**Dominique Louette**, France, Economist
**James MacMillan**, Canada, Economist[2]
**Timothy McBride**, USA, Writer/Editor
**Harold Mickelson**, USA, Maize Breeder[2]
**Mitch Renkow**, USA, Economist
**Scott Rozelle**, USA, Economist
**Daniela Soleri**, USA, Economist
**Gregory Traxler**, USA, Economist
**Robert Tripp**, USA, Anthropologist

## Natural Resources Group

**Larry Harrington**, USA, Director[6]
**Héctor J. Barreto**, Colombia, Senior Scientist, Agronomist (joint CIMMYT/CIAT staff, based in Honduras)
**Peter Grace**, Australia, Senior Scientist, Soils Scientist[1]
**Peter R. Hobbs**, UK, Principal Scientist, Agronomist (based in Nepal)[6]
**Craig A. Meisner**, USA, Scientist, Agronomist (based in Bangladesh)
**Adriana Rodríguez**, Mexico, GIS Technician[1]
**Ma. Luisa Rodríguez**, Mexico, Program Administrator
**Jeff White**, USA, Senior Scientist, Head, GIS/Modeling Laboratory

**Adjunct Scientists**
**Olaf Erenstein**, the Netherlands, Associate Scientist, Economist[2]
**A. Dewi Hartkamp**, the Netherlands, Associate Scientist, GIS/Modeling Specialist
**Eric Scopel**, France, Senior Scientist, Agronomist
**Bernard Triomphe**, France, Scientist, Agronomist[3]
**Christopher Vaughan**, UK, Predoctoral Fellow (based in Zimbabwe)[3]

**Consultants/Research Affiliates**
**David Hodson**, UK, GIS Specialist/Consultant
**Bruce Hungate**, USA, Agronomist
**Scott Justice**, USA, Research Affiliate (based in Nepal)[4]
**Bernard Kamanga**, Malawi, Research Affiliate (based in Malawi)[3]
**Joost Lieshout**, the Netherlands, Database Manager/Consultant
**Monica Mezzalama**, Italy, Plant Pathologist/Consultant
**Zondai Shamudzarira**, Zimbabwe, Research Affiliate (based in Zimbabwe)[3]
**Julio César Velásquez**, Mexico, Research Affiliate[3]
**Jonathan Woolley**, UK, Consultant[4]

**Graduate Students**
**Bruno Basso**, Italy, Michigan State University/USA
**Marcus Bergman**, the Netherlands, Wageningen Agricultural University/the Netherlands
**Kirsten de Beurs**, the Netherlands, Wageningen Agricultural University/the Netherlands
**Marjatta Eilitta**, Finland, University of Florida/USA
**Antoine Findeling**, France
**Serena Stornainolo**, Italy, Michigan State University/USA

## Applied Biotechnology Center

**David Hoisington**, USA, Director
**Ognian Bohorov**, Bulgaria, Scientific Services Officer II
**Natasha Bohorova**, Bulgaria, Senior Scientist, Cell Biologist[6]
**Luz Maria George**, Philippines, Scientist, Coordinator, Asian Maize Biotechnology Network (based in the Philippines)[3]
**Diego González-de-León**, Mexico, Senior Scientist, Molecular Geneticist[2]
**Daniel Grimanelli**, France, Scientist, Molecular Geneticist
**Mireille Khairallah**, Lebanon, Senior Scientist, Molecular Geneticist
**Scott McLean**, USA, Scientist, Geneticist/Breeder
**Enrico Perotti**, Italy, Scientist, Molecular Biologist

**Jean Marcel Ribaut**, Switzerland, Scientist, Molecular Geneticist
**Marilyn Warburton**, USA, Scientist, Molecular Geneticist[3]
**Wanggen Zhang**, China, Scientist, Molecular Biologist[2]

**Associate Scientists**
**Sarah Fennell**, UK, Molecular Geneticist
**Fred Kanampiu**, Kenya, Breeder (based in Kenya)[1]
**Alessandro Pellegrineschi**, Italy, Cell Biologist[3]
**Manilal William**, Sri Lanka, Molecular Geneticist[3]

**Adjunct Scientists**
**Godfree Chigeza**, Zimbabwe, SIRDC/Zimbabwe, Breeder[1]
**Baldwin Chipangura**, Zimbabwe, SIRDC/Zimbabwe, Molecular Geneticist[1]
**Olivier Leblanc**, France, ORSTOM/France, Scientist, Geneticist[1]
**Jang-Yong Lee**, Korea, RDA/Korea, Senior Scientist
**Zachary Muthamia**, Kenya, KARI/Kenya, Breeder[1]
**Kahiu Ngugi**, Kenya, KARI/Kenya, Molecular Geneticist[1]
**Yves Savidan**, France, ORSTOM/France, Senior Scientist, Cytogeneticist[6]
**Antonio Serratos**, Mexico, INIFAP/Mexico, Molecular Biologist
**Kazuhiro Suenaga**, Japan, JIRCAS/Japan, Senior Scientist, Geneticist[3]

**Graduate Students**
**Isabel Almanza**, Colombia, Colegio de Postgraduados/Mexico
**Elsa Espinosa**, Mexico, Colegio de Postgraduados/Mexico[2]
**Susanne Groh**, Germany, University of Hohenheim, Germany[2]
**Héctor Guillén**, Mexico, Colegio de Postgraduados/Mexico[4]
**Ramiro Hernández**, Mexico, Colegio de Postgraduados/Mexico[4]
**John Larsen**, Canada, University of Ottawa/Canada[4]
**Daisy Pérez**, Cuba, Colegio de Postgraduados/Mexico
**Alix Pernet**, France, CIRAD/France[2]
**Celine Pointe**, France, ORSTOM/France[3]
**Gael Pressoir**, France, ORSTOM/France[3]

## Biometrics
**José Crossa**, Uruguay, Principal Scientist, Head
**Chiangjian Jiang**, China, Scientist, Biometrician[4]

**Consultants/Research Affiliates**
**Artemio Cadena**, Mexico[1]
**Jorge Franco**, Uruguay[2]
**Mateo Vargas**, Mexico

## Experiment Stations
**Francisco Magallanes**, Mexico, Field Superintendent, El Batán
**José A. Miranda**, Mexico, Field Superintendent, Toluca
**Rodrigo Rascón**, Mexico, Field Superintendent, Cd. Obregón
**Abelardo Salazar**, Mexico, Field Superintendent, Poza Rica
**Alejandro López**, Mexico, Field Superintendent, Tlaltizapán

## General Laboratories
**Jaime López C.**, Mexico, Supervisor, Soils and Plant Nutrition Laboratory

## General Administration
**Linda Ainsworth**, USA, Manager, Visitors and Conference Services
**Hugo Alvarez V.**, Mexico, Administrative Manager
**Krista Baldini**, USA, Senior Human Resources Manager
**Luis Baños**, Mexico, Supervisor, Drivers
**Zoila Córdova**, Mexico, Manager, Projects and Budgets[1]
**Enrique Cosilion**, Mexico, Supervisor, Housing
**Marisa de la O**, Mexico, Head, International Personnel
**Martha Duarte**, Mexico, Finance Manager
**Carmen Espinosa**, Mexico, Head, Legal Transactions
**Salvador Fragoso**, Mexico, Payroll and Taxes Supervisor
**María Garay A.**, Mexico, Head, Food and Housing
**Gilberto Hernández V.**, Mexico, Training Coordinator
**Gerardo Hurtado**, Mexico, Head, National Personnel
**Héctor Maciel**, Mexico, Manager, Accounting Operations
**Eduardo Mejía**, Mexico, Head, Security
**Domingo Moreno L.**, Mexico, Head, Telecommunications
**Guillermo Quesada O.**, Mexico, Treasury Supervisor[3]
**Javier Robledo**, Mexico, Computer User Support Supervisor[1]
**Roberto Rodríguez**, Mexico, Head, Workshop
**Eduardo de la Rosa**, Mexico, Head, Building Maintenance
**Rorika Rueda**, Mexico, Accounts Payable Supervisor[2]
**Germán Tapia**, Mexico, Warehouse Supervisor
**Manuel Terrazas M.**, Mexico, Treasury Supervisor[4]
**Cristino Torres**, Mexico, Accounts Payable Supervisor[1]
**Miguel Zetina**, Mexico, Computer User Support Supervisor[2]

## Visiting Scientists and Research Fellows[5]
**Hanneke Aalbers**, the Netherlands, Institute of Plant Protection, Wheat Program
**Carlos G. Aguirre Azturrizaga**, Peru, INIA/Peru, Maize Program
**Javed Iqbal Mirza Ahmad**, Pakistan, Ayub Agricultural Research Institute, Wheat Program
**Mohannad Barzegari**, Iran, Seed and Plant Improvement Research Institute/Iran, Maize Program
**Richard Brettel**, Australia, CSIRO/Australia, Wheat Program and Applied Biotechnology Center[4]
**James Brewbaker**, USA, University of Hawaii/USA, Maize Program
**Daniel Calderini**, Argentina, Wheat Program
**William Blas Cerdán**, Peru, Universidad Nacional de Trujillo/Perú, Applied Biotechnology Center[4]
**Nick Chambers**, UK, Agricultural Botany and Crop Genetics, Wheat Program
**Aldo Crossa**, Argentina, Wittenberg University/USA, Applied Biotechnology Center[4]
**Olivia Damasco**, Philippines, University of Philippines at Los Baños/Philippines, Applied Biotechnology Center[4]
**Karim Sayed Fazlul Dewan**, Bangladesh, Dept. of Agricultural Extension/Bangladesh, Maize Program
**Susanne Dreisigacker**, Germany, University of Hohenheim/Germany, Wheat Program
**Ismahane Elouafi**, Morocco, ICARDA/Syria, Applied Biotechnology Center
**Marcelo Edmundo Ferrer**, Argentina, INTA/Argentina, Maize Program
J. Santos Ledesma González, Mexico, UAAAN/Mexico, Maize Program
**Nelson N. Gororo**, Zimbabwe, University of Melbourne/Australia, Wheat Program
**He Kanglai**, China, Guangxi Maize Research Institute/China, Maize Program
**Roger Peter Kinywee**, Kenya, KARI/Kenya, Applied Biotechnology Center
**Keshab Babu Koirala**, Nepal, National Maize Research Program/Nepal, Maize Program
**Xiaowu Lu**, China, University of Hawaii/USA, Maize Program
**Admasu Melake-Berhan**, Kenya, IITA/Nigeria, Applied Biotechnology Center
**Abu Alam Mondal**, Bangladesh, Bangladesh Agricultural Research Institute, Maize Program
**Onias Moyo**, Zimbabwe, SIRDC/Zimbabwe, Applied Biotechnology Center
**Stephen Mugo**, Kenya, KARI/Kenya, Maize Program[4]
**Alejandro Navas**, Colombia, Iowa State University/USA, Applied Biotechnology Center[4]
**August Neumuller**, Austria, Institute for Hydraulics and Rural Water Management, Wheat Program
**Sarah M. Nourse**, USA, University of Hawaii/USA, Maize Program
**Kwandwo Obeng-Antwi**, Ghana, IITA/Nigeria, Maize Program
**Francis Ogbonnaya**, Australia, Victoria Institute for Dryland Agriculture, Applied Biotechnology Center
**Ramón Ibarra Ríos**, Mexico, INIFAP/Mexico, Maize Program
**Mohammed Abdus Salam**, Bangladesh, Dept. of Agricultural Extension, Maize Program
**Raúl Blas Sevillano**, Peru, Universidad Nacional Agraria La Molina/Peru, Applied Biotechnology Center
**Peter Sharp**, Australia, University of Sydney/Australia, Applied Biotechnology Center[4]
**Wolfgang Spielmeyer**, Australia, CSIRO/Australia, Applied Biotechnology Center
**Nigatu Tadesse**, USA, Wheat Program
**Ma. José Vasconcelos**, Brazil, EMBRAPA/Brazil, Applied Biotechnology Center
**Ann Laura Vilhelmsen**, Denmark, Royal Veterinary and Agricultural Institute, Wheat Program
**Emiliano Villordo**, Mexico, UNAM/Mexico, Applied Biotechnology Center
**William Wamala Wagoire**, Uganda, Uganda National Agricultural Research Orgnization, Wheat Program
**Fahong Wang**, China, Shandong Academy of Agricultural Sciences/China, Wheat Program
**Shihe Xiao**, China, CAAS, Wheat Program
**Xu Xiang Yang**, China, Henan Academy of Agricultural Sciences/China, Applied Biotechnology Center
**Habtamu Zelleke**, Ethiopia, College of Agriculture/Ethiopia, Maize Program

1 Appointed in 1997.
2 Left in 1997.
3 Appointed in 1998.
4 Left in 1998.
5 Visited for a minimum of 2–3 months.
6 Project Coordinator.

# In Memoriam

## Gene Saari

This year CIMMYT suffered the loss of an esteemed and long-standing friend: Eugene Saari. Gene retired from CIMMYT in early 1997 after 28 years of valuable service in diverse capacities in the Wheat Program. He passed away on September 21, 1998, after a brief battle against cancer.

Born in Minnesota, Gene got his PhD in plant pathology from the University of Minnesota in 1966. After a brief stint as research fellow at Michigan State University, he initiated his international career in 1967 as a Ford Foundation Post Doctoral Fellow working in India, where he first came into contact with CIMMYT. CIMMYT hired him in 1969, which marked the beginning of a long and fruitful association. Gene served in Asia (India, 1969-73; Thailand, 1980-84; Nepal, 1994-97) and the Middle East (Lebanon, 1973-76; Egypt, 1976-80; Turkey, 1987-90) at different times in his professional life. Between those assignments, he came back to CIMMYT headquarters in Mexico, where from 1990 to 1993 he headed the Wheat Program's crop protection subprogram.

Although a pathologist by training, he also worked as a breeder during certain periods of his professional career. But perhaps his most important contributions came when he was serving as CIMMYT representative in the regions where he worked. His professional expertise, wide experience, and exceptional people skills made him particularly well suited to working in outreach. He was well-respected by his colleagues for his tireless support, genuine concern, and deep commitment to bettering conditions in the developing world. His indefatigable optimism and good humor stood him in good stead when dealing with the complexities of life in outreach.

Gene was a member of a long list of professional associations— among them, the American Phytopathological Society, the Indian Phytopathological Society, the American Society of Agronomy, and the British Society of Plant Pathology. In 1994 he was made a Fellow of the Canadian Phytopathological Society.

For Gene working at CIMMYT was never just a job: it was a calling, a vocation, and CIMMYT feels privileged to have been the organization to which he chose to render his dedicated service.

# CIMMYT Contact Information


**Mexico (Headquarters)** • CIMMYT • Lisboa 27 • Apdo. Postal 6-641 • 06600 Mexico, D.F., Mexico • Fax (international): (52 5) 726 7558/9 • Fax (in Mexico): (91 595) 5 4424/5 • Email: cimmyt@cgiar.org • Primary contacts: **Timothy Reeves**, Director General • **Tiffin D. Harris**, Director, External Relations

**Bangladesh** • CIMMYT • PO Box 6057 • Gulshan • Dhaka-1212, Bangladesh • Fax: (880 2) 883 516 • Email: cm@cimmyt.bdmail.net • Primary contact: **Craig Meisner**

**Bolivia** • CIMMYT • c/o ANAPO • Casilla 2035 • Santa Cruz, Bolivia • Fax: (591 3) 427 194 • Email: cimmyt@bibosi.scz.entelnet.bo • Primary contact: **Patrick Wall**

**China** • CIMMYT • c/o Institute of Crop Breeding and Cultivation • Chinese Academy of Agricultural Sciences • Beijing 100081, China • Fax: (86 10) 6891 8547 • Email: zhhe@public3.bta.net.cn • Contact: **Zhonghu He**

**Colombia** • CIMMYT • c/o CIAT • Apdo. Aéreo 67-13 • Cali, Colombia • Fax: (57 1) 445 0025 • Email: c.deleon@cgiar.org • Primary contact: **Carlos De Leon**

**Costa Rica** • CIMMYT • Apartado 55 • 2200 Coronado • San José, Costa Rica • Fax: (506) 229 2457 • Email: gsain@iica.ac.cr • Primary contact: **Gustavo Sain**

**Ethiopia** • CIMMYT • PO Box 5689 • ILRI Sholla Campus • Addis Ababa, Ethiopia • Fax: (251 1) 611 892/614 645 • Email: cimmyt-ethiopia@cgiar.org • Primary contact: **Wilfred Mwangi**

**Guatemala** • CIMMYT • 12 Calle 1-25 Zona 10 • Edificio Geminis • Torre Norte, 16 Nivel, Of. 1606 • Apdo. Postal 231-A • Guatemala, Guatemala • Fax: (502 2) 335 3407 • Email: jbolanos@ns.guate.net • Primary contact: **Jorge Bolaños**

**Kazakstan** • CIMMYT • PO Box 374 • Almaty 480000 • Kazakstan • Fax: (7 3272) 398379 • Email: karabayev@imbb.almaty.kaz • Primary contact: **Alexei Morgounov**

**Kenya** • CIMMYT • PO Box 25171 • Nairobi, Kenya • Fax: (254 2) 631 499/630 164 • Email: a.diallo@cgiar.org • Primary contact: **Alpha Diallo**

**Nepal** • CIMMYT • PO Box 5186 • Lazimpat • Kathmandu, Nepal • Fax: (977 1) 419 352 • Email: cimkat@mos.com.np • Primary contact: **Peter Hobbs**

**Philippines** • CIMMYT c/o IRRI • PO Box 933 • Manila, the Philippines • Email: m.george@cgiar.org • Primary contact: **Maria Luz George**

**Syria** • CIMMYT • Cereal Improvement Program • ICARDA • PO Box 5466 • Aleppo, Syria • Fax: (963 21) 213 490 • Email: m.nachit@cgiar.org • Primary contact: **Miloudi Nachit**

**Thailand** • CIMMYT • PO Box 9-188 • Bangkok 10900, Thailand • Fax: (66 2) 561 4057 • Email: svasal@loxinfo.co.th • Primary contact: **Surinder Vasal**

**Turkey** • CIMMYT • PK 39 Emek • Ankara, Turkey • Fax: (90 312) 287 8955 • Email: cimmyt-turkey@cgiar.org • Primary contact: **Hans-Joachim Braun**

**Uruguay** • CIMMYT • CC 1217 • Montevideo, Uruguay • Tel/fax: (598 2) 902 8522 • INIA fax: (598 2) 902 3630 • Email: cimmyt@inia.org.uy • Primary contact: **Man Mohan Kohli**

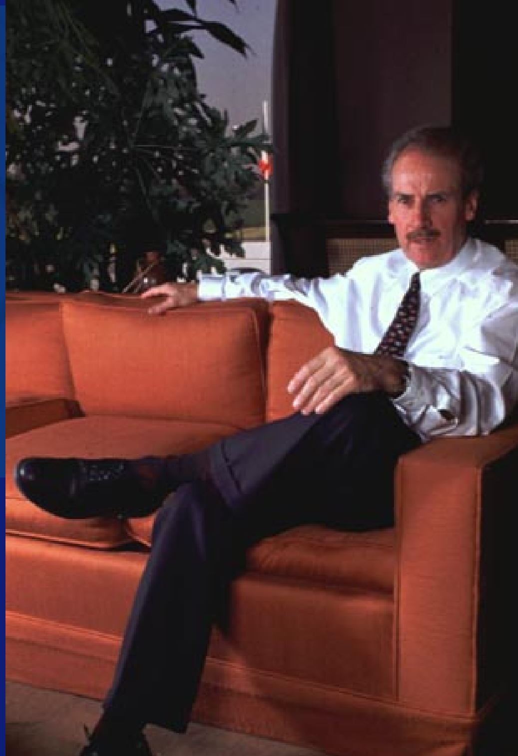
**Zimbabwe** • CIMMYT • PO Box MP 163 • Mount Pleasant • Harare, Zimbabwe • Fax: (263 4) 301 327 • Email: cimmyt-zimbabwe@cgiar.org • Primary contact: **David Jewell**



**Credits**

**Writing and editing:** Mike Listman, David A. Poland, Alma McNab, and Kelly Cassaday, with CIMMYT staff
**Production and design:** Miguel Mellado E., with Juan José Joven C., Eliot Sánchez P., Wenceslao Almazan R., G. Antonio Luna A., and Marcelo Ortíz S.
**Photos:** Kathryn Elsesser, Gene Hettel, Mike Listman, Alma McNab, Michael Morris, Ana María Sánchez, and Hugo Vivar

**Correct citation:** CIMMYT. 1998. *CIMMYT in 1997-98: Change for the Better.* Mexico, D.F.: CIMMYT.
**ISSN:** 0188-9214
**AGROVOC descriptors:** *Zea mays*; wheats; varieties; genetic resources; plant breeding; sustainability; plant biotechnology; economic analysis; innovation adoption; organization of research; research projects; research policies
**AGRIS category codes:** A50, A01
**Dewey decimal classification:** 630



CIMMYT wishes to thank the many governments and organizations who help us fulfill our mission. We are especially grateful to those who provide support for our core activities.

Asian Development Bank
Australia
Austria
Bangladesh Rice Research Institute
Belgium
Bolivia
Canadian International Development Agency
Centre de Cooperation Internationale en Récherche Agronomique Pour le Développement
Centro Internacional de Agricultura Tropical
Colciencias-Colombia
Colombia
Consultative Group on International Agricultural Research
Cornell University
Danish International Development Agency
Department for International Development, UK
Empresa Brasileira de Pesquisa Agropecuaria, Brasil
European Union
Ford Foundation
France
Fundación Guanajuato
Fundación Sonora
Germany
Grains Research and Development Corporation, Australia
Hilton Foundation
India
Instituto Boliviano de Tecnología Agropecuaria
Instituto Nacional de Investigación Agrícola
Inter-American Development Bank
International Centre for Researching In Agroforestry
International Crop Research Institute for the Semi-Arid Tropics
International Development Research Centre
International Food Policy Research Institute
International Fund For Agricultural Development
International Institute of Tropical Agriculture
International Irrigation Management Institute
International Plant Genetic Resources Institute
Islamic Republic of Iran
Italy
Japan
Kellogg Foundation
Leverhulme Trust
McKnight Foundation
Mexico
Monsanto Company
Nacional Financiera
National Institute of Agriculture Research, Uruguay
Netherlands
Nippon Foundation
Norwegian Agency for International Development
Norwegian Ministry of Foreign Affairs
Oregon State University
OPEC Fund for International Development
Pakistan
Patronato Edo. de Sonora
People's Republic of China
Peru
Philippines
Pioneer
Portugal
Republic of Korea
Republic of South Africa
Rockefeller Foundation
Sasakawa Africa Association
Spain
Stanford University
Swedish International Development Cooperation Agency
Swiss Agency for Development and Cooperation
Telmex
Thailand
Tropical Agriculture Research Center, Japan
United Nations Development Programme
United Nations Office for Project Services
United States Agency for International Development
United States Department of Agriculture
University of California
Wisconsin University
World Bank